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United States
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Fort Collins,
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General Technical
Report RM-135



Management and Utilization of Arid Land Plants: Symposium Proceedings

REUNION SOBRE MANEJO Y UTILIZACION
DE LAS PLANTAS DE ZONAS ARIDAS

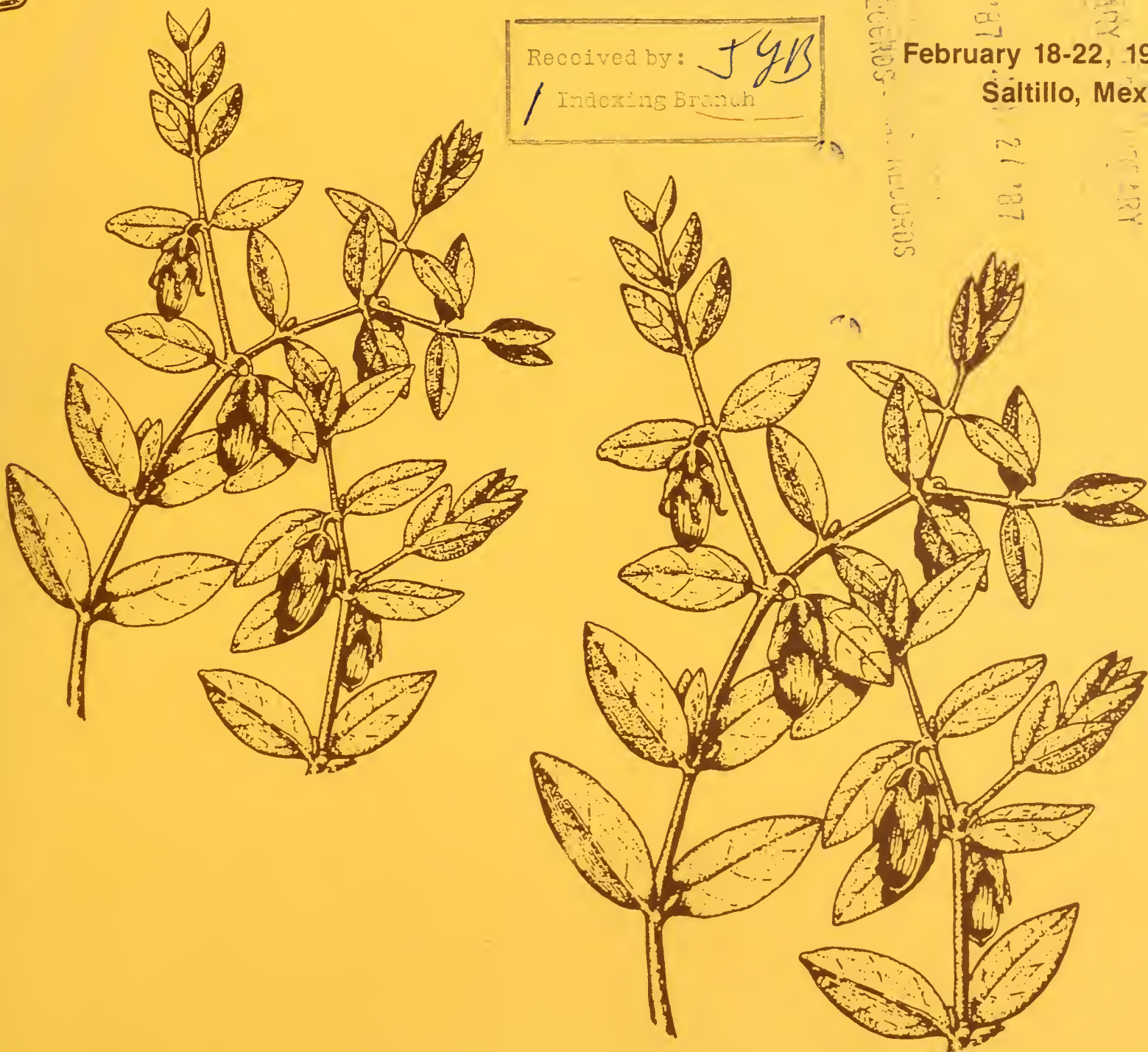
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ABSTRACT

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These proceedings contain 19 papers presented as part of a continuing cooperative effort in forestry and related resources between Mexico and the U.S. Primary species discussed include jojoba, guayule, palms, prickly pear, candelilla, mesquite, buffalo gourd, creosotebush, Indian ricegrass, and yerba del manso. Papers are in the language of the author (Spanish or English) with an abstract in the other language.

Keywords: Arid land plants, desert agriculture

Management and Utilization of Arid Land Plants: Symposium Proceedings

REUNION SOBRE MANEJO Y UTILIZACION DE LAS PLANTAS DE ZONAS ARIDAS

February 18-22, 1985
Saltillo, Mexico

Technical Coordinators:

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Rocky Mountain Forest and Range Experiment Station
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Foreword

In 1981, the USDA Forest Service and SARH Sub-secretaria Forestal de Mexico signed a five-year plan of cooperation to exchange information to improve the professional and technical capabilities of scientists in both countries. The plan included sponsorship of a symposium on inventory, management, and utilization of arid land plant species with economic value. The symposium was held February 18-21, 1985 at Saltillo, Mexico. Papers were presented during a three day meeting with one day devoted to a field trip to the Campo Experimental Station "La Saucedá." Over 200 scientists, technicians, and administrators, attended the symposium. This General Technical Report includes papers presented in the language of the author (English or Spanish) with a summary at the end in the other language.

International meetings require considerable preparation and the involvement of many people. Recognition for the successful symposium in Saltillo must be given to Luis Segura, Lorenzo Maldonado, and Miguel Caballero from Instituto Nacional de Investigaciones, and Bob Partido, Reggie Fletcher, Bob Hamre, and Diane Prince from USDA Forest Service. Carlos Gonzales was our counterpart in Mexico for organizing the meeting and selecting papers. All the papers presented represent the opinion of individual authors who were responsible for their own peer review, manuscript preparation, and editing.

DAVID R. PATTON and ALVIN L. MEDINA
Technical Coordinators

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Potencial del Guayule Bajo Cultivo en Zonas Áridas del Norte de México¹

Dr. Alfonso López Benítez²

Resumen.--El guayule, especie vegetal que se encuentra en parte de las zonas áridas de México, es potencialmente útil debido a que contiene en promedio un 10% de hule natural, lo que según reportes oficiales, representa una reserva de 300 mil toneladas de hule natural, mientras que México actualmente requiere importar alrededor de 40,000 toneladas anuales.

El aprovechamiento actual de la especie es nulo y para su explotación se requieren aún varios estudios, por lo cual se han realizado una serie de investigaciones agronómicas que cubren diferentes aspectos del cultivo del guayule, algunas de las cuales se presentan en este trabajo.

INTRODUCCION

Convencionalmente en México se ha considerado como zona árida aquella área geográfica que recibe una precipitación pluvial anual de no mayor de 250 mm, y como semiárida aquella que recibe una precipitación entre 250 mm. y 500 mm.

En la República Mexicana existen aproximadamente 809,000 Km. cuadrados con este tipo de zonas, en las cuales se calcula que vive el 17% de la población del país, cuyos habitantes económicamente activos se dedican principalmente a actividades de subsistencia como: agricultura rudimentaria, pastoreo y recolección de especies vegetales silvestres utilizables. Esto se traduce en miseria, migración hacia los centros urbanos y desperdicio de recursos naturales y humanos

Existe sin embargo, en buen número de especies vegetales nativas potencialmente utilizables cuyo manejo y explotación "in situ" así como su domesticación y cultivo son potencialmente una considerable fuente de trabajo y recursos económicos para esas zonas consideradas como marginadas.

Una de esas especies es el guayule cuya distribución natural esta confinada a pendientes y laderas con suelos calcáreos y pedregosos con altura de 900 a 2300 msnm; una precipitación media anual de 250 a 380 mm y una variación de temperatura de -10°C en invierno a 40°C en verano.

¹ Ponencia presentada en la Reunión Sobre Manejo de Plantas en Zonas Áridas. Saltillo, Coahuila, México. Febrero 18-22, 1985.

² Ph.D. Jefe del Programa de Guayule del Departamento de Fitomejoramiento de la UAAAN. Saltillo, Coahuila. México.

La importancia que tiene el guayule para México consiste en 1). En su habitat natural contiene en promedio un 10% de hule natural, 2). En las zonas áridas del norte de México, existen aproximadamente 3 millones de toneladas de arbusto equivalentes a 300 mil toneladas de hule natural (según informe de CONAZA 1972-1976), 3). En promedio México produce solo el 10% de subnecesidades internas de este producto, por lo que tiene que importar anualmente alrededor de 40,000 toneladas. Con la explotación del guayule en las zonas áridas se vería beneficiada la población existente en ellas.

Actualmente el aprovechamiento de este recurso es nulo y para explotar su potencial se requiere de investigación para desarrollar la tecnología necesaria, evaluar la factibilidad económica de su explotación y evaluar su repercusión socioeconómica.

Las áreas de investigación que hasta ahora se han atendido son: 1). Producción de planta y establecimiento de lotes experimentales de riego y de temporal, 2). Densidad de población por hectárea y edad óptima para la cosecha, 3). Estudios de fertilización, 4). Plagas y enfermedades, 5). Mejoramiento Genético y 6). Formación de un Banco de Germoplasma.

Entre los problemas primero abordados fue el mejorar la germinación de la semilla, para lo cual, primero se limpia de residuos florales, se trilla, y se eliminan las brácteas de la semilla hasta obtenerla limpia, posteriormente se le sumerge en agua por 8hs, y se le aplica un tratamiento de hipoclorito de sodio (Na O Cl) al 3% durante 30 minutos y para semilla nueva recién cosechada se le da un tratamiento adicional de ácido gibberelico de 100 ppm. durante 3 horas. Con lo que se obtiene una germinación mayor del 80%.

Con esto se puede obtener la cantidad de plántulas necesarias en invernadero para establecer los lotes experimentales deseados para cualquier estudio.

Con el objeto de obtener información sobre el cultivo del guayule bajo condiciones de temporal y de riego, y evaluar su potencial de producción, se han realizado una serie de estudios agronómicos que cubren diferentes aspectos del cultivo de esta planta y que en forma resumida se presentan a continuación:

- 1). Evaluación de tres densidades de población por hectárea bajo condiciones de temporal.

Con una precipitación medio anual de 325 mm se estableció este estudio en el que se utilizaron dos espaciamientos entre surcos (71 y 61 cm.). Con tres distancias entre plantas que dieron densidades de 23,000, 28,000 y 33,000 plantas por hectárea. Los parámetros evaluados fueron altura de planta, diámetro de copa, contenido de resinas y contenido de hule. Los datos obtenidos indicaron que a los cuatro años de edad no había diferencias estadísticas entre las diferentes densidades, pero en cuanto a desarrollo vegetativo la densidad de 33,000 plantas por hectárea fue ligeramente superior.

- 2). Respuesta del guayule a 4 niveles de riego en tres densidades de población por hectárea.

Los niveles de riego fueron cada 45 días, cada 60 días, cada 120 días y un riego por año. Las densidades de población fueron 40,000, 55,000 y 65,000 plantas por hectárea. Los parámetros evaluados fueron altura de planta, diámetro de copa, contenido de hule y contenido de resinas. Los datos obtenidos indicaron diferencias estadísticas para riego y densidad de población. Siendo el tratamiento de riegos cada 60 días y 40,000 plantas por hectárea estadísticamente superior en cuanto a desarrollo vegetativo y contenido de hule.

- 3). Determinación de contenido de hule diferentes materiales.

En su gran mayoría los materiales hasta ahora evaluados para contenido de hule provienen de poblaciones silvestres donde existe una amplia variación genética.

Se han colectado 2,850 de las que se han analizado por contenido de hule 322 colectas destacando los del estado de Durango. Las pruebas preliminares de contenido de hule indican que que bien pueden compararse con algunas de las variedades mejoradas obtenidas del Laboratorio Nacional de Servicio de Semillas de Estados Unidos.

El potencial de producción de hule del guayule puede apreciarse mejor en una prueba de contenido de hule de 15 diferentes genotipos, que se realizó bajo un diseño experimental de bloques completos al azar con cuatro repeticiones y una densidad de población por hectárea de 27,000 plantas con dos riegos en primavera. En esta prueba a los tres y cuatro años de edad, el genotipo N-593 destacó por su porte bajo, 41.6 cm. de altura y su alto porcentaje de hule en base a su peso seco, 11.4% y 12.17%. También resultaron consistentemente altos en contenido de hule en dos años los genotipos N-573, G-11624 y G-11646. En cuanto a contenido de hule en gramos por planta los genotipos G-11604 y G-11605 resultaron con mayor contenido de hule. Con una producción estimada por hectárea de 2.3 y 2.2 toneladas por hectárea respectivamente. Esta producción en un período de tres años puede considerarse aceptable. Sin embargo existen algunos otros materiales que aparentemente superan bajo condiciones de temporal a los mejores genotipos aquí evaluados como son los introducciones 76023, 76060 y 76028-5 con 13.62, 13.60 y 13.61 por ciento de hule respectivamente.

Summary.-- Guayule, a shrub species found in arid zones of Mexico, has potential uses given its mean content of 10% natural rubber. Official reports indicate national reserves of approximately 300,000 tons of natural rubber. Mexico produces 10% of its internal needs, and imports almost 40,000 tons of rubber annually. The use of guayule as a resource is currently virtually non-existent, and to develop its potential will require various studies dealing with the different aspects of cultivation, some of which are presented here.

245 (Management and Improvement of Guayule Germplasm)¹

Himayat H. Naqvi²

Abstract.--Guayule (Parthenium argentatum Gray) is a potential rubber producing crop for the arid land areas. The ecologically fragile natural guayule populations that were exploited in the past need to be protected as valuable biological resources, and not used as raw material for industry. At UC Riverside, procedures have been developed to properly manage and utilize guayule germplasm, and to further improve it through selection and hybridization. Significant progress has been made in the domestication and commercialization programs.

INTRODUCTION

The world demand for rubber has been steadily increasing since its original discovery by Charles Goodyear in the middle of the last century. Hevea brasiliensis, a native of South America, provided most of the original supplies of commercial rubber. The plant is now successfully domesticated in tropical Asia where it dominates the world market. In addition to Hevea, many other plants, mostly belonging to families Moraceae, Euphorbiaceae, Asclepiadaceae, Apocynaceae, and Asteraceae, were investigated and occasionally utilized as local sources of rubber. The most extensive use, thus far, of any North American rubber plant has been that of guayule (Parthenium argentatum Gray, of the family Asteraceae), a Texan-Mexican shrub that has been going through ups and downs of research and development efforts since at least the middle of the 19th Century.

Historical Aspect

The guayule plant was scientifically discovered in Texas by Dr. J. M. Bigelow in 1852, while he was attached to the Mexican Boundary Survey Commission. It was later botanically described by Professor Asa Gray of Harvard University. The plant was, however, known to the natives on both sides of the border long before that. The conquering Spaniards, reaching Mexico in the 1500s, noted a game played with a small, very resilient ball made of pure rubber obtained by communal mastication of the bark of guayule and some other related plants.

Another primitive use of guayule was as a fuel that may be partly responsible for its absence in places where it would be naturally expected. Due to its high resin content, the plant burns with a fierce smokey flame so that whenever it was available, it was invariably used as fuel for the crude Mexican adobe smelters, light torches, home heating, and bread ovens. This practice was later stopped or slowed down when the value of the plant was known, but by then, thousands of acres of guayule had already been depleted.

Commercial Exploitation

According to Lloyd (1911), guayule rubber was brought to public attention for the first time in 1876 by an exhibition sent from Durango, Mexico, to the Centennial Exposition at Philadelphia. The Natural History Society of Mexico also took up the study of the plant in the same year and reported the presence of rubber of good quality in its bark. During the next few years, many companies were established in the United States and Mexico, and small-scale rubber-testing programs were carried out. The earliest efforts seem to have centered around San Luis Potosi in Mexico, which may be regarded as the birthplace of industrial guayule rubber. In 1902, a factory was established at Jimulco by the Compania Explotadora de Caucho Mexicano that put the guayule rubber on the market for the first time in 1905. At about the same time, certain American businessmen successfully adapted the mechanical extraction method that used a pebble mill. During the next few years, many factories were built at Torreón, San Luis Potosi, Saltillo, Monterey, Gomez Palacio, and Jimulco. Factories were later established at Marathon, Texas, and elsewhere. All of these factories were utilizing wild guayule shrub from the wild stands in Mexico and Texas. From 1910 to 1946, Mexico exported more than 68 million kg of guayule rubber to the United States, and much of that rubber was used in the manufacture of automobile tires.

¹Paper presented at the Symposium on Management and Utilization of Arid Land Plants. [Saltillo, Mexico, February 18-22, 1985].

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Natural resources are not unlimited, especially under arid conditions. Soon, the wild populations of guayule shrub were depleted to a point where most of the factories were forced to close down (Hammond and Polhamus 1965). The four owned by the Continental Rubber Company remained open for a little longer, but they foresaw the need for carrying out cultural operations that were initiated in 1910. These operations were later transferred to San Diego, California, then to Arizona, and finally to Salinas, California, where cultural and chemical operations continued for the next few years. During World War II, these operations of the Intercontinental Rubber Company were taken over by the U.S. Forest Service to carry out the wartime Emergency Rubber Project. More than 40,000 hectares of guayule were planted over the next 3 years and an extensive research and development program was initiated to study all phases of guayule commercialization activity.

At the end of the war, the entire rubber outlook changed. In December 1945, funds for the guayule project were frozen and the project was ordered liquidated in its entirety as of December 1946. This resulted in the destruction of an estimated 10 million kg of rubber standing in the field. Limited research activity did continue in a few organizations in the U.S., Mexico, and some other countries, but without major breakthroughs.

Present Outlook

The high mobility of modern civilization depends mainly on two commodities, namely the petroleum as a liquid fuel for vehicles and the rubber which is used for tires and other components of these engines. These two products also play an important role in other aspects of high technology and, as a result, have become symbols of economic and strategic security for most countries of the world.

Presently, there are two main classes of rubbers that are commonly used in every day life:

- 1) Natural rubbers that are derived from plant sources, especially Hevea brasiliensis, and
- 2) Synthetic rubbers derived from petroleum by-products. Although the overall demand for synthetic rubbers has been on the rise, natural rubber, nevertheless, is preferred due to improved elasticity, resilience, tackiness, and low heat buildup. It is, therefore, essential for the manufacture of high quality airplane and automobile tires as well as for other high duty industrial components.

Hevea brasiliensis, the current major source of natural rubber in the world, is a tropical tree that cannot be grown in the United States and other arid and semiarid parts of the world. Most such countries have to import natural rubber from tropical Asia, and other parts of the world. The United States, alone, spends nearly one billion dollars annually to buy this strategically essential commodity from outside sources, causing lots of economic and security concerns. These concerns

turned into fears during the Arab Oil Embargo of the early 1970's, and attention was once again turned to find alternate sources of natural rubber that can be grown in the semiarid environment. The U.S. National Academy of Sciences (1977) intervened and appointed a panel of experts from the U.S. and Mexico to consider guayule as a possible alternative. The panel strongly recommended guayule to be grown as a natural source of rubber in the United States and other countries with semiarid environments. This initiated a series of new research and development projects in the United States that also stimulated many researchers in other countries to follow suit. The Congress of the United States passed the Native Latex Act in 1979, providing money for guayule work. USDA, NSF, and other organizations allocated funds for guayule research that came into national and international focus once again. The Critical Agricultural Materials Act of 1984 ensures further efforts in this direction. New scientific knowledge and experience acquired during the past few years has shown that economic and technological feasibility is near. Recent analysis of guayule rubber has shown that it is equal to hevea in physical as well as chemical properties, and can be substituted for hevea in most applications. The inherent low concentration of rubber in the early germplasms is being improved through a major breeding program at the University of California, and other agronomic investigations are being carried out at the universities and the Agriculture Research Service Laboratories in the four southwestern states. A chemical extraction process has been developed by the Texas A&M University, and research is also being conducted to determine the value of resins, bagasse, and other by-products to enhance commercialization efforts.

CURRENT STATUS OF GUAYULE GERMPLASM

Our brief survey of guayule native populations in Mexico (Naqvi and Hanson, 1983a), and that of Tipton and Gregg (1982) for Texas populations, revealed a wide range of variability in rubber content and environmental responses in various populations. Rubber contents varied from as low as 6% to over 19% on the dry weight basis. Guayule populations were generally found at altitudes from 700-3,000 m, and topographic and climatic conditions also varied from place to place. All these varied niches and wide distances between most guayule populations provided excellent opportunities for the development of ecotypes and races resulting in a significant variability within and between populations. Using raw seed from these populations for whatever purpose can be a wasteful experience. On the other hand, bringing these valuable sources of germplasm into a systematic improvement program can be a useful proposition. An improvement program is also essential for commercializing guayule as a rubber-producing crop in today's high industry requirements. It is estimated that the existing sources of guayule germplasm need at least two-fold improvement in rubber content before it can be accepted as a commercial crop. The potential

Table 1.--Early guayule selections¹ included in comparisons provided by Hammond and Polhamus (1965).

Selec. #	Synonym	Applicable information	Selec. #	Synonym	Applicable information
11591----	-----	Open-pollinated selection from 4265-I.	A-48124----	11633----	See 11633.
11600----	-----	Do.	A-48143----	-----	Hammond collection from northern Zacatecas. Good at Salinas.
11604----	-----	Do.	N-396----	-----	Single plant selection from Hammond collection.
11605----	-----	Do.	N-566----	-----	Open-pollinated selection from 4265-I.
11609----	-----	Do.	N-575----	A-58143	See A-48143.
11619----	-----	Do.	N-576----	A-48116	See A-48116.
11633----	A-48124	Hammond collection having smaller plants, but higher total rubber.	N-596----	11635----	See 11635.
11634----	-----	72-chromosome; from open-pollinated, 36-chromosome cross between SP-7 and SP-8	12229----	-----	From single-plant selection from progeny of open-pollinated 2106 and guayule <u>Parthenium tomentosum</u> var. <u>stramonium</u> .
11635----	596----	72-chromosome controlled cross between 54-chromosome 4265-I plant and a plant of 36-chromosome.	12231----	A-48115	See A-48115
11646----	A-48121	Hammond collection with superior performance at Salinas.	593----	-----	Commercial variety developed by the Intercontinental Rubber Company.
11693----	N-563----	72-chromosome cross found among plants in a 54-chromosome 4265-I selection.	4265----	-----	Collected by Powers in Durango in 1942. Highly variable.
11701----	-----	72-chromosome descendant of open-pollinated cross between 54-chromosome 4265-I and 36-chromosome unknown.	4265-I----	-----	Selected from 4265 by Johnson; 54 chromosomes; variable.
A-48115----	12231----	Hammond collection.	4265-II----	-----	Open-pollinated selection from 4265.
A-48116----	N-576----	Hammond collection with good performance at Salinas.	4265-X----	-----	Selected from 4265-I by Taylor and Benedict; 72 chromosomes; higher rubber content and more uniform than 4265-I.
A-48118----	-----	Hammond collection.	4265-XF----	-----	Seed increase of selected plants from 4255-X.
A-48121----	11646----	See 11646.			

¹Seeds of most of these strains have been placed in storage at the USDA Laboratories at Fort Collins, Colorado.

is there if it is properly exploited without damaging the fragile arid ecosystems inhabiting guayule.

The first step in any management and improvement program is to locate and collect the existing sources of guayule seed. The largest reservoir of guayule germplasm exists in nature growing mainly in the Chihuahuan Desert and adjacent areas in southern Texas and northcentral Mexico (Naqvi and Youngner, 1984). Due to sporadic cultural operations during the past 70 years, some germplasm sources do exist elsewhere. One of the important sources is maintained at the USDA Seed Storage Laboratory at Fort Collins, Colorado (USA). These include many USDA guayule lines that have been salvaged from the Emergency Rubber Project of the 1940s and others, and are available to researchers (table 1). Some germplasm is also available from other public and private research groups, but most of them stem from the USDA lines and/or from collections made from the wild guayule stands. Some

recent collections include those made by Rollins in 1976, and Naqvi and Hanson in 1977 (Knoblock 1979). Most of these sources of seed have been accumulated at the University of California, Riverside, and are being managed and tested accordingly. In 1982, seven certified varieties of guayule germplasm were released jointly by USDA and the University of Arizona, Texas A&M University, New Mexico State University, and the State of California (Niehaus 1983) and are available to growers (table 2).

Table 3 gives a comparative evaluation of the three of these lines grown at Riverside, Tucson, Mesa, and Las Cruces. Two points are evident: (1) there is significant variability in rubber content within and between these lines, and (2) the Riverside samples are more similar to those in Arizona in terms of rubber content. Las Cruces plants show higher values. Rubber, like other quantitative traits, is influenced by environment to a significant extent.

Table 2.--Seven cultivars of guayule released jointly by the Agricultural Experiment Stations of Arizona, California, New Mexico, and Texas, and the USDA-ARS (adapted from Niehaus 1983).

Cultiv.#	Description	Cultiv.#	Description
N-565	High rubber-yielding at Shafter, 1957 Plant uniformity rating, ¹ 94.0% Percent rubber, ² 7.3, 6.2, 8.4 Rubber yield, ³ 1369 lbs/acre	11605	High rubber yielding at Salinas, 1950s Plant uniformity rating, 70% Percent rubber, 6.8, 4.4, 8.4 Rubber yield, 1125 lbs/acre
11619	High rubber yielding at Salinas, 1950s Plant uniformity rating, 95% Percent rubber, 4.4, 3.4, 7.0 Rubber yield, 1319 lbs/acre	12229	High rubber yielding at Shafter, 1958 Plant uniformity rating, 95% Percent rubber, 5.3, 4.4, 6.0 Rubber yield, 1042 lbs/acre
11591	High rubber-yielding at Salinas, 1950s Plant uniformity rating, 95% Percent rubber, 4.4, 3.4, 7.0 Rubber yield, 1250 lbs/acre	N-576	High rubber yielding at Salinas Plant uniformity rating, 95% Percent rubber, 5.6, 4.9, 7.1 Rubber yield, 1030 lbs/acre
11604	Plant uniformity rating, 90% Percent rubber, 5.5, 4.8, 8.4 Rubber yield, 1348 lbs/acre		

¹Plant uniformity rating conducted at Arizona and New Mexico. ²Percent rubber values for Tucson, Mesa, and Las Cruces, respectively, at 3 years. ³Rubber yield values are averages for 3 locations at 3 years.

PROPAGATION AND AGRONOMICS

Seed Germination

As a member of the family Asteraceae, the seed-bearing flowers in guayule are arranged on a capitulum. There are five female flowers in a capitulum and, theoretically, one seed per female flower. Some of these seeds, however, may be lacking embryos. Guayule is a long-day plant, and flowering is mainly dependent upon the irrigation frequency. In nature, of course, it will depend upon the precipitation. It is a prolific seed producer and under optimum moisture conditions can produce 3-4 crops during the growing season that begins in mid-spring and lasts to early fall. When the floral heads are mature,

they can be easily collected manually or with the help of a mechanical device.

An unthreshed guayule seed unit consists of an achene, two attached staminate florets and a subtending bract. The first step, therefore, is to separate the achene from its enclosing structure. For small samples, the seed units are threshed between a rubber abrader and the Tyler Standard 20- and 10-mesh sieves. For larger lots, a mechanical thresher can be adopted. Forsberg #2 Huller equipped with rubber cylinder and liner proved useful in many organizations. After threshing, the chaff is removed from the seed using a Dakota Blower or a clipper office tester equipped with appropriately sized sieves (Toukdarian *et al.* 1983).

Table 3.--Variability in rubber content in three guayule lines grown at UCR, and comparative evaluation with the same lines grown at Tucson, Mesa, and Las Cruces. These three lines are among the seven USDA lines released for commercial purposes.

Sample No.	11605		11604		11591	
	Rubber (%)	Height (cm)	Rubber (%)	Height (cm)	Rubber (%)	Height (cm)
1	4.62 A	33.00	7.37 A	40.00	7.00 A	38.00
2	4.27 A B	38.00	5.60 B	33.00	5.62 B	40.00
3	4.00 B C	41.00	5.60 B	25.00	5.35 B	37.00
4	3.95 B C D	33.00	5.50 B	45.00	5.07 B C	38.00
5	3.92 B C D	33.00	5.27 B	36.00	4.60 C	41.00
6	3.65 C D E	50.00	4.20 C	35.00	3.85 D	32.00
7	3.55 D	42.00	4.10 C	43.00	3.25 E	39.00
8	2.67 E	29.00	4.52 C	44.00	2.70 E	33.00
x at UCR	4.04	43.30	5.27	37.60	4.98	37.20
SD+	0.32	11.40	1.14	6.70	1.21	3.19
LSD @ 5%	0.3811		0.5425		0.5736	
x Tucson	4.4	70% planting	5.5	90% planting	4.4	95% planting
x Mesa	3.4	uniformity	4.8	uniformity	3.4	uniformity
x Las Cruces	7.0	rating	8.4	rating	7.0	rating

A large number of guayule seeds are empty, i.e., without embryos. These empty seeds are lighter than the filled ones and are, to some extent, removed with the chaff during the cleaning operations. For a complete removal of these empty seeds, a small test gravity table can be used effectively. Another way of overcoming this problem is to soak the seeds for 1-2 minutes in an organic solvent of low specific gravity. The heavier filled seeds will sink to the bottom and the light, empty seed will float at the top and can be discarded. Pentane, isopentane, and some alcohols proved very effective without causing damage to the seeds. Table 4 shows the result of one such test.

Guayule seed has inherent dormancy and needs special pretreatment in order to germinate. Appropriate procedures have been developed to overcome this problem (Naqvi and Hanson 1980, 1983b). Seeds are soaked and washed in water to improve permeability and remove toxic seed inhibitors (Naqvi and Hanson 1982). They are then treated with a mixture consisting of equal parts of sodium hypochlorite and gibberellic acid for 2 hours. The concentration of sodium hypochlorite used for this purpose depended upon the postharvest age of the seed. For freshly harvested seeds, a concentration of 1.0% by available chlorine is most suitable. With increasing age, the concentration should be decreased accordingly. Two-hundred ppm of gibberellic acid serve the best purpose for seed of all ages. After pretreatment, the seed can be directly sown or dried and kept for later use. The results of a germination test with one seed lot is shown in table 5.

Field Planting

Pretreated guayule seed can either be planted directly in the field or grown into seedlings in a greenhouse and later transplanted in the field. Direct seeding in the field has not been very successful at the moment due to low competitive ability of young guayule seedlings and their

Table 4.--Separation of filled guayule seed in organic solvents of different specific gravities.¹

Organic solvents used for soaking	Percent germination in:	
	Top fraction	Bottom fraction
pentane	1.5	82.0
iso-pentane	4.0	81.0
benzene	13.0	92.0
ethanol	34.0	87.0
chloroform	46.0	71.1

¹Approximate number of guayule seed were soaked in each solvent, and the two fractions thus separated were each germinated separately and percent germination determined thereof. The seed that germinated were considered filled seed with embryos, the rest were empty seed.

Table 5.--Comparative effects of various treatments on germination and radicle growth in three-month-old wild guayule seed collected near San Pedro del Gallo, Durango, Mexico.

Seed treatment	Germination (%)	Radicle growth (mm)
Unwashed	59.0	5.1
Washed	63.0	5.3
Washed + NaOCl	79.0	5.7
Washed + GA ₃	82.0	6.4
Washed + NaOCl + GA ₃	92.0	7.0

sensitivity to drought conditions. Some degree of success in direct seeding has been achieved, utilizing a new concept known as "fluid drilling." This involves the direct sowing of pretreated and partially germinated seed into the soil, using a gel carrier that enables the guayule seedlings to become established rapidly and help it to compete with the much faster-growing weeds. A constant mist for the first few days helps the young seedlings to overcome drought stress. This process still needs further improvement to become commercially acceptable.

For all practical purposes, guayule seedlings are raised in the greenhouses. Pretreated seeds are sown in flats filled with well-drained media and kept moist in the greenhouse. Seeds germinate in a week and are pricked in individual pots. Seedlings can be transplanted in the field in about 6-8 weeks. Various stages of propagation and greenhouse management can be mechanized to save time and money. Field transplanting can also be accomplished, using mechanized farming equipment. Field design and management will depend upon the objectives of the experiments to be conducted. In general, about 25,000 plant per hectare have shown good results (Hanson *et al.* 1979; Siddiqui *et al.* 1979).

GERMPLASM IMPROVEMENT

Selection Procedures

Existing guayule germplasm occurs in various ploidy levels, including diploids ($2N = 36$), triploid ($2N = 54$), tetraploids ($2N = 72$), and even higher levels. In general, the diploid germplasm is sexual in reproduction, but higher ploidy plants are mostly apomictic. Although various ploidy level plants occur in nature, apomictic tetraploids are more prevalent. Most of the USDA lines, which were originally selected from the wild populations, are facultative apomicts. A recent screening of 19 USDA lines growing at UCR revealed a range of 3-7% rubber in these plants. Further analysis of variance showed that plants were significantly different within and between most lines in terms of rubber contents (Naqvi 1985). As a result, they offer a better opportunity for selections that may prove relatively more stable in time.

Improvement of the existing guayule germplasm is carried out through standard selection procedures. Plants under selection are grown in experimental plots at Riverside and Palmdale. The latter is our closest version of a high desert situation located at an average altitude of about 1,000 m. In general, plants are grown at the rate of about 25,000 plants per hectare and maintained at optimum growing conditions. In southern California, summers are dry and winters are wet. As a result, irrigation is only applied during the summers on an if-needed basis. For USDA lines and other sources that have passed through some degree of selection, an average of eight plants are selected per line and analyzed for rubber and other traits. For other sources of seeds, each plant is selected and analyzed.

Presently, the major selection criteria include improved yield (biomass and rubber), cold tolerance and disease resistance. Plant height and width are the usual parameters measured for biomass determinations, although fresh and dry weights are considered frequently.

Two parameters are considered for rubber monitoring: (1) rubber quantity based on percent dry weight of the sample, and (2) rubber quality based on molecular weight determinations of the rubber in samples. Plant sampling is done in such a way that it does not destroy the entire plant. A number of branches of average diameter of 1.0 cm are taken from the lower portions of the plant, dried in a forced-air oven at 60°C for 48 hours, and then ground in a Model 4 Thomas-Wiley Laboratory Mill, using a 2-mm mesh screen. Freezing the dried samples in liquid nitrogen prior to grinding can facilitate grinding and avoid too frequent cleaning of the equipment. For quantitative rubber analysis, we use a modified photometric procedure (Perry *et al.* 1983; Naqvi *et al.* 1984). This procedure has the advantage over other standard procedures in that it can utilize as low as 1.0 g sample, and the measurements compare well with others (Banigan *et al.* 1982; Black *et al.* 1983). Rubber molecular weight, as a measure of its quality, is determined through gel permeation chromatography using ultrastyrigel columns (Campo-Lopez and Agulo-Sanchez 1975; Naqvi *et al.* 1984). Tetrahydrofuran is used as a solvent for rubber extraction as well as a solvent system in the GPC. Chromatograms obtained for each sample are compared with the polystyrene standards prepared earlier and converted into polyisoprene equivalents using standard calculations.

Seeds are collected from plants with high rubber contents and other desirable traits. These seeds are germinated and planted in the field for the second cycle of observation and testing. The selected progeny is put through a replicated yield trial and the final selections are increased and distributed as improved guayule cultivars. Selections for improved cold tolerance and disease resistance are also tested in accordance with the prescribed breeding procedures.

Table 6.--Some high-rubber guayule selections made at UC Riverside as compared to USDA var. 575 used as a control. All new selections have higher average rubber with less variability within each entry.

Entry #	Mean Rubber ¹	Range
P-40-101	10.2	9.2 - 11.2
P-48-13	8.9	7.1 - 11.0
P-48-24	10.6	9.0 - 11.7
P-50-51	7.7	7.1 - 8.4
N-575 ²	6.9	5.5 - 6.9

¹Average of 7-8 samples, each replicated twice.

²From published data (Naqvi 1985). This variety exhibited highest % rubber in an earlier trial.

Table 6 shows the results of one set of second cycle high-rubber selection progeny. It is evident that these lines are relatively more uniform with much higher population mean than those in the first cycle in just one cycle of selection pressure. A few cycles of selection should ultimately produce germplasm lines with high rubber and other desirable traits. Figure 1 shows some of these selections growing in the field at UC Riverside.

Interspecific Hybridization

In addition to guayule, genus *Parthenium* also includes 16 other species that range in gross morphology and habit from an ephemeral annual to perennial trees, and also in ecological requirements inhabiting deserts to subtropics (Rollins 1950). Despite these differences, most species have similar floral structure and chromosome numbers, and are easily crossed with each other producing fertile hybrids. Most other species of *Parthenium*, however, do not have significant quantities of high quality rubber, although they do possess other characteristics that are desirable for a guayule germplasm improvement program (Youngner *et al.* 1985). These include increased biomass associated with increased total rubber per plant, cold tolerance, and resistance to disease and pest infestations. Table 7 provides a list of *Parthenium* species used in the hybridization program at UC Riverside. We are currently using at least three species for biomass improvement. These include *P. schottii*, *P. tomentosum*, and *P. fruticosum*, and are all trees reaching up to 8 m in height (Naqvi 1982; Naqvi *et al.* 1983, 1984). These plants are also sources of improved disease and pest resistance (Cheo and Beupre 1981). *P. incanum*, *P. integrifolium*, and *P. alpinum* are used for imparting cold tolerance to guayule. Most of these species occur in diploid and polyploid forms, but only diploids are currently used for interspecific hybridization purposes. Diploid forms of most *Parthenium* species are self-incompatible, but are compatible



Figure 1.--Left: Close-up of a 4-year-old guayule plant reaching up to 1 m in height. Right: Various high-rubber guayule selections growing at UCR.

Table 7.--A list of Parthenium species that are used in the germplasm improvement program at UC Riverside. Some species exist in more than one type.

Taxon	Habit/Habitat	Breeding Need
SECTION PARTHENICHAETA		
<u>P. tomentosum</u>	Small deciduous trees, tropical, subtropical, thorn forests (500-1500 m)	Improve biomass and disease resistance
<u>P. fruticosum</u>		
<u>P. schottii</u>		
<hr/>		
<u>P. argentatum</u>	Densely pubescent shrubs, Chihuahuan Desert, primarily on limestone.	Improve cold tolerance and rubber
<u>P. incanum</u>		
<u>P. rollinsianum</u>		
<hr/>		
SECTION POLYPHYTUM		
<u>P. alpinum</u>	Small perennial shrubs, montane (2500-3000 m), on gypsum outcrops.	Improve cold tolerance
<u>P. ligulatum</u>		
<hr/>		
SECTION PARTHENIASTRUM		
<u>P. integrifolium</u>	Perennial tuberous herbs, grass-land prairies and temperature deciduous forests.	Improve cold tolerance, more water requirement
<u>P. hispidum</u>		
<hr/>		
SECTION ARGYROCHAETA		
<u>P. hysterothorus</u>	Annual and perennial herbs, temperature lowlands.	Adopt to annual habit
<u>P. confertum</u>		

with other species. Emasculation is, therefore, not necessary. Interspecific hybridization is carried out under controlled conditions in the greenhouse, as well as in the open-pollination field plots. Rubber analysis and morphological investigations of new taxa are carried out routinely.

Preliminary rubber analysis of some Parthenium species and hybrids are provided in table 8. Figure 2 gives a view of some of these taxa in the field. These results clearly indicate that: (1) interspecific hybridization is possible between guayule and most other species, (2) F_1 hybrids have inherited much higher biomass than their guayule parents, (3) rubber contents of these hybrids are somewhat intermediate between the two parents, and (4) they have inherited high molecular weight rubber like their guayule parents. These trends are very important and it is expected that further germplasm improvement is possible through further crossing and back-crossing of these taxa. The ultimate objective is, of course, improvement in biomass and rubber quantity and quality in the newly developing taxa.

DISCUSSION AND CONCLUSIONS

It has been established without any doubt that natural rubber is an essential industrial and strategic commodity in the United States and other industrialized societies. It is also a biological fact that the tropical rubber tree

Table 8--Preliminary determinations of rubber contents in some Parthenium species and their F_1 hybrids. Values are based on the analysis of some 2- to 4-year-old plants growing at UCR field station.

Taxa	Rubber Quantity (%)	Approximate mol. wt.
<u>P. argentatum</u>	0.30 - 13.00	> 2,000,000
<u>P. schottii</u>	0.05 - 0.50	< 5,000
<u>P. fruticosum</u>	0.05 - 0.50	< 5,000
<u>P. tomentosum</u>	0.10 - 0.50	< 50,000
Hybrid A x S	2.00 - 3.00	> 1,000,000
Hybrid A x F	2.00 - 3.00	> 1,000,000
Hybrid A x T	1.00 - 2.50	> 1,000,000
<u>P. incanum</u> ¹	1.00 - 2.00	> 150,000
<u>P. rollinsianum</u> ¹	1.00 - 4.00	> 150,000
<u>P. alpinum</u> ¹	1.00 - 2.00	> 150,000
<u>P. integrifolium</u>	1.00 - 1.50	< 50,000

¹Data courtesy of Jan West.

Hevea brasiliensis cannot be grown in the U.S. and other countries with predominantly arid climates. It is, therefore, important that alternate sources of natural rubber should be explored in order to avoid economic and political crises in the future. The concept is not new and it was experimented in the past with varying degrees of success.



Figure 2.--Left: 4-year-old guayule plants growing in front of same age Parthenium tomentosum plants. Right: 2-year-old F_1 hybrid between guayule and P. tomentosum. It is already larger than the 4-year-old guayule parent.

In the beginning of the century, Africa stood second to South America in the amount of rubber supplied for world consumption. The continent reached its maximum in the year 1906 with shipments amounting to over 20,000 tons. Most rubber came from the wild species including Funtumia (F. elastica, especially), Landolphia, Chilandra, Carpodinus, Mscarenhasia, and others. Rubber production declined during the next few years due to indiscriminate harvesting and destructive collection practices. In America, a search also continued for finding good sources of natural rubber, but without lasting effects. The Central American rubber tree, Castilla elastica, was utilized as a rubber source since at least 1903, although historically it was used by the natives long before that. During the same period of time, many species of Jatropha, Pedilanthus, Plumeria, and Euphorbia, were experimented in Mexico and were found to contain rubber, but none were really exploited commercially. In the United States, species of Chryothamnus, Haplopappus, Asclepias, and some other plants were also tried with small successes, but without lasting results. The only plant that showed significant promise and continued to attract the attention of scientists and others is the guayule rubber plant that had its own share of ecological crises and mishandlings that were described earlier.

Two important lessons can be learned from this discussion: (1) guayule offers the best alternative to hevea, especially for countries in the arid and semiarid regions, and (2) natural plant resources are finite and cannot tolerate the pressures of indiscriminate harvesting and mismanagement.

In the United States, it is more or less accepted that guayule domestication and agronomic studies need to be done to commercialize guayule as a competitive crop. Although significant amounts of seed are available, the priority is to improve this seed through breeding programs in order to make it an economically feasible crop. In Mexico, on the other hand, the emphasis is on utilizing the native stands of guayule as raw material for industry. There are no exact estimates of the total shrub available in the wild. A system analysis provided by Anderson (1981) estimates the maximum sustainable yield from the guayule wild stands to be in the neighborhood of 2,700,000 tons. These and other investigators in Mexico and elsewhere believe that if these resources are once again utilized as raw material for the industry, they will be depleted within less than a decade. A proper reforestation and management program may, however, slow down the depletion process indefinitely.

From a genetic point of view, each guayule plant in nature is a unique combination of genes. Instead of using them as raw material, they can better be utilized in a systematic improvement program, and may result in the development of superior lines. These improved lines can later be utilized for reforestation or cultural operations. Establishment of germplasm banks and

improvement centers in the native guayule areas can provide jobs as well as improved germplasm and raw material that can be used locally or shipped elsewhere as viable export commodities.

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Resumen.--Guayul (Parthenium argentatum Gray) es un hule con la potencial de producir una cosecha en areas aridas. Las poblaciones naturales y frágil ecológicamente, que fueron explotadas en pasado, necesitan de ser protegidas como recursos biológicamente valiosos, y no usadas como materia prima para industria. En UC Riverside, se han desarrollado metodologías para el propio manejo y utilización de germen plasma del guayule, y para además mejorarlo por selección y habridación. Progreso significativo se ha hecho en programas de domesticación y comercialización.

Manejo de Poblaciones Silvestres de Jojoba en Baja California¹

Jorge I. Sepulveda B.²

Resumen.--Poblaciones silvestres de jojoba son un recurso economico importante para los habitantantes dentro la area de distribución. El uso de jojoba debida ser un base de información derivada de metodologías fuerte. Las poblaciones son un fuente de germen plasm que se puede usar en el futuro para la comercialización de las cosechas. Para establecer quías para usos, es necesario (1) tener un inventario de las poblaciones naturales y las arcas de distribución; (2) establecer areas protegidas de uso, para hacer observaciones sobre la fenología, y proveer protección contra factores adversos como ramoneo, incendios, etc; (3) seleccionar areas para reforestación por las propias agencias. La coordinación de activades sobre manejo por las agencias respectivas es importante para el futuro de el recurso.

INTRODUCCION

El nuevo enfoque que se le esta dando actualmente a las zonas áridas y semiáridas de México, considerandolas como un verdadero potencial en cuanto a las diferentes especies que lo componen, ha permitido que día a día, al traves de la luz de los estudios científicos, se haya ido ampliando el horizonte de su participación en los procesos productivos de la economía nacional. Son numerosas las especies tanto del desierto chihuahuense como en el sonorense que estan siendo aprovechadas y que de una u otra forma constituyen una fuente alterna de ingresos de las poblaciones rurales de estas regiones.

En el caso particular del desierto sonorense, indudablemente es la jojoba, cuyas características, cualidades y usos son por todos conocidas.

En el presente trabajo se pretende conceptualizar la jojoba en el marco de su aprovechamiento y manejo en forma silvestre, con las bondades de sus beneficios y sus peligros asi como tambien, basado en las experiencias derivadas de traabajos de investigación, se establecen algunas perspectivas futuras para la jojoba en el ambito de su aprovechamiento y conservación: es decir, como un recurso renovable.

ANTECEDENTES

Con el objeto de establecer un marco de referencia para esta reunion, mencionaremos algunos conceptos basicos sobre la jojoba, que para el caso de este trabajo constituyen elementos de suma importancia para comprender la interrelacion que

¹ Ponencia presentada en la Reunión Sobre Manejo de Plantas en Zonas Aridas. Saltillo, Coahuila, México. Febrero 18-22, 1985.

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guardan los diversos factores que deberan tomarse en cuenta para establecer los criterios en su manejo y aprovechamiento.

HABITAT NATURAL

Distribucion

El origen de la jojoba, asi como su distribución en tiempos remotos, no son claros aun, no obstante y debido a su habito de crecimiento y reproduccion, se infiere que esta especie tuvo su origen a lo largo de la costa del pacifico en un clima de tipo mediterraneo, es decir, en la region noroccidental de los estados de Baja California y California, en Estados Unidos.

La distribución actual de las poblaciones de jojoba son el resultado de una serie de factores bioticos y abioticos que la han confinado a la situación que guarda actualmente. Estos factores, por tener una participación determinante, se mencionan a continuación.

Orografia

La orografía es uno de los elementos que intervienen en la distribución de la especie, actuando algunas veces como verdaderas barreras, por su parte la fisiografía se encuentra muy relacionada con la presencia de poblaciones de jojoba.

En estudios realizados por diversas instituciones nacionales se constata una marcada preferencia en el habito de la jojoba a localizarse en ladera y lomerios, relacionado esto directamente a la acumulación de humedad y nutrientes.

El limite altitudinal en el que se encuentra la jojoba en México fluctua entre 5 m a 1000 msnm,

correspondiendo este limite maximo a los pies de monte de las sierras de Juarez y San Pedro Martir en Baja California.

Suelos

La jojoba en su distribución prospera con muy variados tipos de suelos, aun cuando existe la evidencia de una marcada preferencia de esta especie con suelos de origen granítico con pedregosidad superficial que van de las arenosas, como en las dunas costeras, a las arcillo-arenosas, con drenajes de medios a rapidos, y con escasa materia organica y nitrogeno.

Clima

Uno de los factores mas importantes y determinantes en la vida de la planta de jojoba y en el aspecto económico desde el punto de vista del interes del hombre, sin duda es el clima. Si bien es cierto que los factores anteriormente mencionados son importantes para la presencia de las poblaciones silvestres de jojoba en su area de distribución, es el clima quien determina de manera definitiva la producción de la semilla, la cual constituye basicamente el interes por esta especie. precipitación, temperatura y distribución de esta en diferentes epocas del año determinan el aumento disminución de la producción de semilla, limitadas estas evidentemente por los factores genotipicos de la especie.

Como se habia mencionado con anterioridad, la especie prospera mejor en un clima de tipo mediterraneo, es decir, con un porcentaje mayor de lluvia de invierno que de verano y una distribucion que vaya de noviembre a abril esta característica climática corresponde a la porcion noroccidental del estado de Baja California y coincidentemente es la region con mayor densidad en poblaciones y con una producción mayor que la del resto del área de distribución en los estados de Baja California sur y Sonora, los cuales poseen regimenes de lluvia de verano, siendo estos ultimos menos efectivos debido a las altas temperaturas, humedad relativa baja y gran evaporacion.

La cantidad de precipitacion, aun cuando es importante, se considera que su distribución es el factor determinante de una buena produccion, es preferible una baja precipitacion distribuida convenientemente, que una grande torrencial y efimera.

En terminos generales, la jojoba tolera precipitaciones en un rango que va de los 100 a los 500 mm.

La temperatura junto con la precipitacion se interrelacionan para conformar las diferentes condiciones climáticas en el área de distribución de la jojoba.

En terminos de la especie, esta tolera altas temperaturas hasta de 50°C. En cambio, las bajas

temperaturas entre los 0° y -60°C pueden tener efectos negativos importantes en la floracion y en general en la fisiología de la planta.

Vegetación

De acuerdo a shreev en la demarcacion de las áreas fitogeográficas del desierto sonorense, la jojoba se localiza en todas las regiones señaladas por el autor, lo que indica la gran adaptabilidad de la especie para asociarse a las diversas comunidades vegetales que constituyen ese desierto.

Existe algo importante a destacar en relación a la vegetación y, de acuerdo a estudios realizados, algunas plantas actuan como especies protectoras de la jojoba en su etapa juvenil. Por lo tanto, para el manejo de poblaciones silvestres, este hecho constituye un criterio fundamental a emplear.

Fenología

Quizá uno de los procesos de mayor interes económico es lo referente a las etapas fenológicas de la especie que determinara en el proceso de formación de la semilla.

La maduración del fruto varía segun el área que se trate. En el estado de Baja California, la producción de semilla se efectua en los meses de junio-julio, mientras que en Baja California sur la maduración del fruto tiene lugar en los meses de marzo-abril. Las diferencias anteriores se encuentran intimamente relacionadas principalemnte a la estacionalidad de las lluvias en las diferentes areas, como ya se había anotado anteriormente.

Estas diferencias en la maduracion del fruto en ocasiones acarrea problemas en el buen manejo de las poblaciones que repercuten tanto en la condición de la planta como en la calidad del producto que se obtiene. Esta situación se complica aún mas cuando en la misma planta la maduracion del fruto no es uniforme, observandose diferentes estadios logicos simultaneamente.

DIAGNOSTICO DEL APROVCHAMIENTO Y MANEJO DE LAS POBLACIONES DE JOJOBA

El aprovechamiento de los rodales silvestres ha sido una actividad realizada para diferentes propositos desde hace cientos de años por los antiguos pobladores del desierto sonorense: no obstante la presión que ejercian estos aprovecha-mientos, era minima en cuantia y en el impacto indirecto que ocasionaba lo anterior, debido principalmente al empleo que se le daba, a las poblaciones humanas relativamente bajas y al no madismo de las tribus, que en cierta forma evitaba una sobreplotacion en una area determinada.

En terminos generales se puede decir que el hombre vivía en equilibrio con esta especie.

Con el devenir de los tiempos, en aumento de la población, en desarrollo tecnológico en la agricultura y la introducción del ganado caprino y bovino y la apertura de vias de comunicacion han ocasionado un impacto considerable a las poblaciones silvestres de jojoba.

En el año 1954 se inicio, aunque en Baja escala, el aprovechamiento de la jojoba silvestre, al instalarse en la empresa laboratorios jojoba, la semilla utilizada provenia de Sonora y Baja California sur principalmente. Fue hasta el año 1972, a raíz de la primera reunion internacional sobre jojoba, cuando se disparo el interes sobre la especie. Una presion gradual pero creciente se fue aplicando a las poblaciones silvestres en toda el area de su distribucion natural y que evolucionaria de la fase experimental hasta los sistemas actuales de aprovechamiento.

¿Como se han manejado las poblaciones de jojoba y cuales son los metodos que se han aplicado?

Debido a que la jojoba es apetecida por el ganado tanto bovino como caprino, las poblaciones silvestres son afectadas fuertemente por el ramoneo de estas especies, asi es que unos de los primeros trabajos que se han realizado para mejorar su condición es la protección de los rodales con cercos de alambre de puas. De acuerdo a datos obtenidos por diversas instituciones, se calcula un total aproximado de 8,000 ha que se encuentran protegidas de la acción del ganado.

Desmontes

Dentro del manejo que se les ha dado a las poblaciones silvestres se incluyen los desmontes. Que van de las selectivas, o sea las que elimina solo aquellas especies que en una o otra forma dificultan el aprovechamiento, a los desmontes totales, dejando unicamente la jojoba. Los desmontes por lo general son manuales e incluyen la quema de las especies eliminadas.

Labores Culturales

Las labores culturales que actualmente se aplican a los rodales son la formacion de microcuencas para la captacion de aguas de escurrimiento, encontrandose de varios tipos: cajetes, herraduras, zonjas, etc., y de acuerdo al terreno esto se hace en forma manual o con maquinaria.

Tambien dentro de las labores culturales se usan las curvas a nivel.

Podas

Otras labores que se han aplicado a las poblaciones, aunque por su costo no se ha extendido, son las podas de estimulo y de formación.

Recoleccion de Semilla

Una de las actividades mas importantes dentro del manejo de las poblaciones son las referentes a la recolección del fruto, y es en esta etapa en donde se conjugan los aspectos economicos y de conservacion.

Si se parte de la base de la jojoba constituye un elemento de un sistema que involucra una gran cantidad de interacciones tanto bióticas como abióticas, su manejo debera cimentarse sobre estudios ecologicos.

En el caso particular de la semilla, se estima que de un total que cae al suelo, un 95 por ciento es depredado por roedores, existiendo de un 2 a un 5 por ciento que tiene posibilidades de llegar a estapa de plantula.

Debido a este indice tan alto de depredación, la recolección del fruto se hace cuando la capsulacion no se ha desprendido de la planta. Este hecho hace que la recolección del fruto se realice en un tiempo en el cual la maduracion de la semilla no se completa totalmente, lo que aunado a que la fructificacion no es uniforme en la misma planta ocasiona que la recolección se haga indiscriminadamente en frutos con diferentes etapas de maduración.

Reforestacion

Dentro de los trabajos de reforestación que se han realizado en poblaciones silvestres de jojoba a lo largo de la peninsula de Baja California, destacan los de coteper (antes coplamar), entre los años de 1980-1984 se calcula que se realizaron reforestaciones en unos 3000 has. aproximadamente. Desafortunadamente por diversos problemas tecnicos y economicos estas actividades si bien no se han suspendido, estas han disminuido en forma notable.

Los trabajos de reforestación realizados implicaban la recolección de fruto, producción de planta y plantación en las areas cubiertas por jojoba o zonas aledañas a las misma. Las actividades de reforestación ademas de tener su efecto de conservación del recurso tambien mantuvo un importante repercusión social, como ejemplo de ello se puede mencionar que, en el estado de Baja California se generaron por este concepto entre el periodo de 1980-1982 un total de 228,000 jornales.

SITUACION ACTUAL DEL MANEJO DE POBLACION SILVESTRE DE JOJOBA

Se considera actualmente que para poder tener un buen manejo de poblaciones de jojoba se deberan involucrar aspectos que van desde la organización de productores, aprovechamiento, comercialización e industrialización de la cera liquida.

La falta de conocimiento, tanto de autoridades como de poseedores del recurso ocasionaron que, hasta el año de 1978 el aprovechamiento y manejo de las poblaciones de jojoba se realizara en forma desordenada propiciandose una serie de actividades que asentuaban contra el recurso.

En la actualidad se han obtenido algunos logros con la aplicación de diversas normas de aprovechamiento y conservación que repercuten en obtener un manejo mas adecuado de las poblaciones de jojoba, a continuación y a manera de ejemplificar lo anterior se exponen los procedimientos que se siguen actualmente en el estado de Baja California sobre el particular.

Zonificación de áreas productoras en base a estudios de maduración de la semilla (Mapa 2), aun cuando existen variaciones importantes en cuanto a la maduración de la semilla en las diversas áreas de distribución provocados por factores climáticos principalmente, la experiencia ha demostrado que en terminos generales existe un gradiente de maduración de la semilla de jojoba en el estado de Baja California que se inicia en el extremo sur de la entidad y termina en la porción norte del mismo, no obstante cada año se requiere realizar inspecciones que determinen el estado fenológico que guardan cada zona en particular, para el efecto se han estado establecido sitios permanentes de observación fenológica y dasométrica. La zonificación en este último caso además de los aspectos climáticos se han seleccionado en base a criterios de tipos de vegetación, suelos, productividad y de importancia social, de tal forma que las zonas son representativas de la mayoría de la producción de semilla de jojoba en el estado de Baja California.

Los datos obtenidos sirven de base para programar y aplicar el estudio dasométrico que previene la ley forestal para cualquier aprovechamiento de este recurso.

El estudio dasométrico clásico, encuentra una variación en la especie de jojoba y esta es debido básicamente a que año con año deberán realizarse muestreos que permitan evaluar la producción de semilla de jojoba en un área determinada.

Para la obtención de la producción se realiza un muestreo que transferido a la fórmula de tamaño de muestra nos indica la cantidad de sitios que se requieran muestrear en cada sitio se levantan diversos datos que se presentan en los cuadros uno y dos.

Como se ha de observar la metodología que se esta aplicando actualmente quizá no cumpla con los requisitos necesarios para la obtención de una información mas formal, no obstante los beneficios colaterales que se han obtenido como son el de establecer un vínculo de comunicación entre posee-

dores del recurso, autoridades y empresarios que comercializan e industrializan la cera líquida de jojoba, ha permitido subsecuentemente una mejor concientización sobre el manejo y aprovechamiento de las poblaciones silvestres de jojoba en la península de Baja California.

Finalmente y a manera de recomendación, solicitamos se revitalice el comité coordinador de normas y estudios para la preservación y fomento de la jojoba, el cual conformaba una serie de elementos que permitían normar los aspectos técnicos y legales a fin de hacer congruente un programa nacional del aprovechamiento de la jojoba.

CONCLUSIONES Y RECOMENDACIONES

En base a los criterios expuestos se establece que las poblaciones silvestres de jojoba son una fuente alterna importante de recursos económicos de los Grupos humanos que habitan en su área de distribución.

-Que su aprovechamiento deba estar basado en información derivada de metodologías y prácticas adecuadas para su uso persistente.

-Que es fuente potencial para la obtención de germoplasma para apoyar las futuras plantaciones comerciales.

-Que para establecer los criterios de aprovechamiento se requieran los siguientes elementos:

1. Inventario de las poblaciones naturales en el área de su distribución.
2. Zonificación ecológica de los diferentes rodales para establecer sitios permanentes de observación fenológica.
3. Protección de las poblaciones a factores adversos como: ramoneo, plagas, enfermedades e incendios.
4. Selección, bajo criterios ecológicos, de las zonas de reforestación que lleven a cabo diversas instituciones para que se garantice el éxito de la misma.

-Finalmente, que se propicie una coordinación interinstitucional adecuada para el óptimo manejo y aprovechamiento de este importante recurso forestal.

Abstract.--Wild populations of jojoba are a source of germplasm to be used in commercialization of future crops. In order to establish use guidelines it is necessary to; (1) have an inventory of natural populations and areas of distribution, (2) establish protected sites for making phenological observations and provide protection from adverse factors such as grazing, fire, etc., (3) select areas for reforestation by appropriate agencies. Coordination management activities by respective agencies is vital for the future of the resource.

245 Estimating Production and Utilization of Jojoba¹

Bruce A. Roundy, George B. Ruyle and Jane Ard²

Abstract.--Twig weights of jojoba (Simmondsia chinensis) from three sites in southern Arizona were highly correlated with the square of twig internode diameter. Diameter measurements can be used to estimate the production of this important browse and its utilization by livestock and wildlife. Utilization estimates based on percentage of twigs browsed may be inaccurate.

INTRODUCTION

Jojoba (Simmondsia chinensis) is a drought-tolerant long-lived evergreen shrub of the Sonoran desert in northwestern Mexico and the southwestern United States. It grows best on well-drained, well-aerated, coarse soils associated with desert foothills and washes from 600 to 1200 m (Gentry 1958). The high content and desirable properties of wax esters in jojoba seed (Scarlett 1978) have led to extensive research on the chemistry, use and cultivation of this desert shrub (Elias-Cesnik 1982). But jojoba is also the best browse species for wildlife and livestock within its range (Kearney and Peebles 1964). Jojoba has historically been used by goats, sheep and cattle (Mills and Foster 1982) and provides food for rodents and birds (Gentry 1958, Sherbrooke 1976, Thomson 1976, Martin et al. 1951), javelina (Pecari tajaco) (Knipe 1956), desert bighorn sheep (Ovis canadensis) (Russo 1956), and mule deer (Odocoileus hemionus) (Judd 1962, McCulloch and Urness 1973, Urness et al. 1977). Yet, little is known about the proper utilization and management of jojoba as a forage (Mills and Foster 1982). Observations are that jojoba is grazing tolerant (Judd 1962) but may have reduced seed production (Gentry 1958), reduced growth (Mills and Foster 1982) and reduced survival (Judd 1962) with heavy grazing. However, the impacts of grazing on jojoba have not been quantified (Mills and Foster 1982) so management guidelines used are those followed for other shrubs (e.g. Garrison 1971), including limits of 40% utilization under continuous grazing and 50% utilization under a rest rotation grazing system (U.S.D.A. Forest Service 1979). Utilization is generally estimated by determining the percentage of current year's twigs that have been browsed (U.S.D.A. Forest Service 1979). This method may overestimate actual

weight utilization, especially where use is high (Stickney 1966, Jensen and Scotter 1977, Ruyle et al. 1983). A more accurate but more tedious method of estimating utilization is that of using least squares regression analysis to determine the relationship between twig weight and twig length or diameter (Rutherford 1979). Diameters or lengths of browsed and unbrowsed current year's twigs can then be measured to estimate the weight left and weight removed to calculate utilization. The purpose of this research is to examine methods of estimating jojoba utilization. Specific objectives include: (1) to compare the relationship of stem diameter to twig weight components of jojoba growing on different sites, (2) to determine the relationship of percent browsed twigs to percent weight removed by grazing, and (3) to determine the effects of different grazing intensities on distribution of leaves and twigs.

METHODS

Three sites were selected for initial jojoba sampling to develop diameter-weight relationships. The sites were located on the eastern slope of the Tucson Mountains, the southern foothills of the Santa Catalina Mountains, and in the area of the Horrell enclosure on the northern foothills of the Mazatzal Mountains south of Roosevelt Lake, all in southern Arizona. Associated soils are gravelly sandy clay loams and principle associated vegetation includes Franseria dumosa, Larrea tridentata and Acacia constricta at the Tucson and Santa Catalina sites, Encelia farinosa at the Santa Catalina site and Cercidium microphyllum, Lycium pallidum, and Larrea tridentata at the Roosevelt site in addition to jojoba.

During the summer of 1984, large branches were sampled from 20 ungrazed shrubs at each of the three sites. To determine the relationship between fresh and oven-dried twig diameter, the mid-internode diameter of 150 twigs ranging in water content from 9 to 52% was measured before and after drying in an oven at 70°C for 24 hours. Thereafter, all samples were oven-dried and minimum mid-internode diameter and leaf, stem and total weight measured. Measurements for branches from each site included a

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minimum of 20 branches with diameters 3.05 to 5 mm and a minimum of 141 twigs with diameters ≤ 3 mm. Leaf widths, lengths and weight of leaf pairs were also recorded. Oven-dried weight parameters were regressed on oven-dried mid-internode diameter. Regression slopes and intercepts for the different sites were statistically compared ($p \leq 0.05$) using methods described by Snedecor and Cochran (1971).

Additionally, large branches on two moderately grazed areas near the Roosevelt site were sampled to determine the relationship between percent of twigs browsed and percent weight removed by grazing. The Horrell area is grazed year long and the Burnt Corral area was grazed four months prior to sampling. At each area three branches having a minimum of 10 twigs of current year's growth were sampled from each of 20 shrubs. Branches were oven-dried, numbers of grazed and ungrazed twigs were counted, and twig diameters were measured at the point of grazing for current and previous years' twigs. All remaining current and previous years' twigs with a mid-internode diameter ≤ 3 mm were weighed. Weight removed by grazing was estimated using previously developed regression equations and divided by total weight to give an estimate of percent utilization by weight. Percent utilization by weight was regressed on percent browsed twigs and utilization estimates by number of browsed twigs and by diameter measurements were statistically compared ($p \leq 0.05$) in a nested one-way analysis of variance. All twig

diameters were measured to the nearest 0.05 mm with a dial caliper and weights were measured to the nearest mg.

To estimate the effects of grazing on shrub leaf and twig distribution within the canopy, main branches were clipped from 20 shrubs having received light, moderate, and heavy browsing from cattle. The shrubs were at the Roosevelt site and were associated with different distances from water. For each main branch, number of leaf pairs and current and previous years' twigs were counted in 5-cm cross sections perpendicular to the main branch. Shrub components for the different grazing treatments were compared by analysis of variance and Duncan's multiple range test.

RESULTS AND DISCUSSION

Twig weight components of jojoba were most highly correlated with the square of oven-dried mid-internode diameter (table 1, fig. 1). Coefficients of determination (r^2) were higher when twig diameters between 3 and 5 mm were included in the analyses than when only twig diameters ≤ 3 mm were analyzed. Because of the higher sample size, the coefficients of determination are a better indication of twig weight variability with respect to mid-internode diameter for the smaller diameter twigs than the larger diameter twigs. It was observed that twigs greater than 3 mm diameter

Table 1.-- Intercepts(a), regression coefficients(b), coefficients of determination (r^2), and standard errors of estimate (S.E.E.) for jojoba twigs on three sites in southern Arizona of the form: $y = a + bx^2$, where y is oven-dried weight(g) and x is oven-dried mid-internode stem diameter (mm).

Site	Number observations	Leaf weight				Stem weight				Total weight			
		a*	b*	r ²	S.E.E.	a	b	r ²	S.E.E.	a	b	r ²	S.E.E.
Stem diameter ≤ 5 mm													
Roosevelt	180	-0.42b	0.48a	0.85	0.84	-0.29a	0.25a	0.91	0.34	-0.72b	0.72a	0.89	1.09
Tucson	162	-0.47a	0.42b	0.90	0.61	-0.36b	0.24a	0.92	0.31	-0.83a	0.66b	0.92	0.88
Santa Catalina	178	-0.28a	0.34c	0.85	0.63	-0.30b	0.21b	0.92	0.28	-0.59a	0.55c	0.90	0.82
Sites combined	510	-0.43	0.42	0.85	0.75	-0.33	0.24	0.91	0.31	-0.75	0.66	0.89	0.99
Stem diameter ≤ 3 mm													
Roosevelt	153	-0.12b	0.30a	0.82	0.19	-0.07a	0.12a	0.56	0.14	-0.17a	0.41a	0.81	0.27
Tucson	141	-0.08a	0.24b	0.84	0.20	-0.12a	0.13a	0.73	0.14	-0.20b	0.37a	0.83	0.32
Santa Catalina	157	-0.20a	0.28a	0.83	0.25	-0.13a	0.13a	0.82	0.12	-0.32b	0.41a	0.85	0.33
Sites combined	451	-0.12	0.27	0.81	0.22	-0.10	0.13	0.73	0.14	-0.22	0.39	0.83	0.31

* Intercepts and regression coefficients for different sites followed by the same letter are not significant different ($p \leq 0.05$) according to the elevation and slope tests of Snedecor and Cochran (1971).

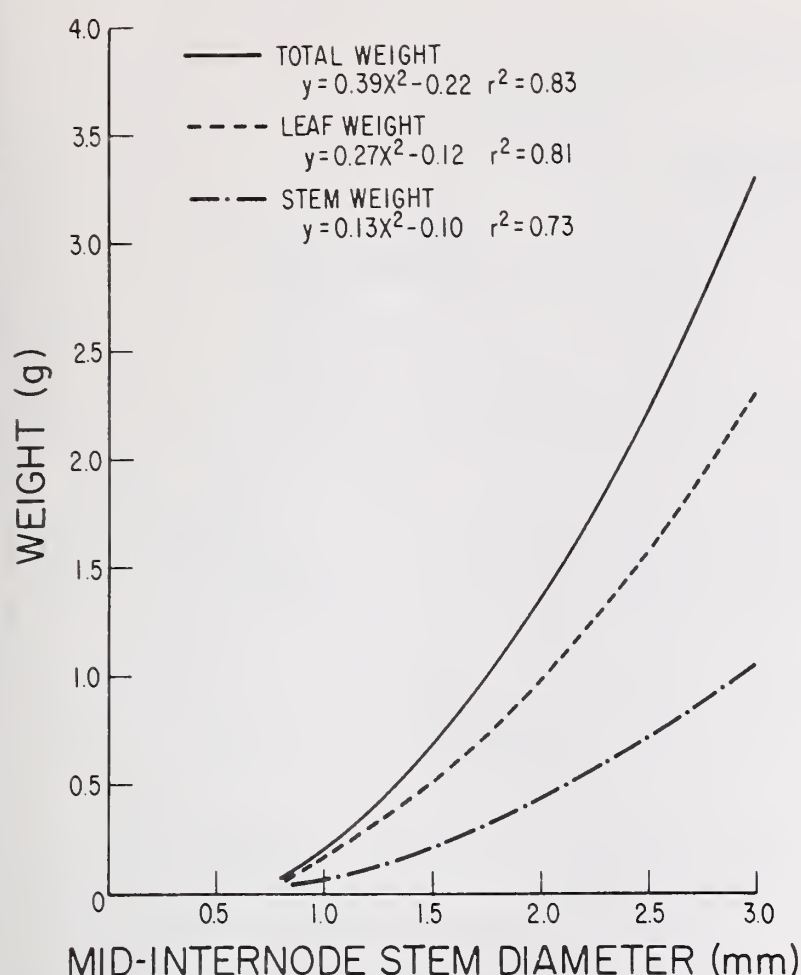


Figure 1.--Leaf, stem and total oven-dried weight of jojoba twigs in relation to oven-dried mid-internode diameter for twigs with diameter ≤ 3 mm.

were rarely grazed so the regressions for the smaller diameter twigs should be more useful than those including the larger diameter branches in estimating utilization. Regressions for the larger diameter branches indicate the potential of diameter-mass equations for estimating total biomass of jojoba.

Regression coefficients and intercepts had greater variation among sites when large diameters were included in the regression analysis than when only smaller diameters were analyzed (table 1). Regression coefficients and intercepts of equations for estimating leaf weights varied more among sites than those estimating stem weights from small twig diameters.

Leaf weight accounted for an average of 73% of the total twig weight for small diameter twigs and was similar for all three sites. Mean leaf weights and size were also similar for all three sites (table 2). Estimates of total twig weight for small diameter twigs varied less than 0.3g among the three sites sampled. There was a high correlation ($r^2 = 0.99$) between fresh (x) and oven-dried mid-internode diameter (y) where:

$$y(\text{mm}) = 0.922x(\text{mm}) - 0.142$$

This high correlation indicates that twig weight of jojoba can be estimated from measurements taken on the plant or from oven-dried samples. Equations for estimating total weight will be

Table 2.--Mean weights, lengths and widths of jojoba leaf pairs on three sites in southern Arizona

Site	No. of samples	Leaf pair weight (mg)	Leaf length (mm)	Leaf width (mm)
Roosevelt	153	159.7a	23.8b	9.5a
Tucson	141	137.2a	23.0b	9.0a
Santa Catalina	157	146.7a	26.6a	10.0a

Means in columns followed by the same letter have overlapping 95% confidence intervals.

most useful in calculating jojoba utilization by cattle since they tend to browse twigs and leaves of jojoba nonselectively. The coefficients of determination of twig diameter and weight are not quite as high for jojoba on these sites as has been found for many large-leaved eastern shrubs (Telfer 1969) or for western shrubs such as deerbrush (*Ceanothus integrifolius*) ($r^2 = 0.97$, Bartolome and Kosco 1982), snowberry (*Symphoricarpos oreophilus*) ($r^2 = 0.90$, Ruyle et al. 1983), blackbrush ($r^2 = 0.94$, Provenza and Urness 1981), and bitterbrush (*Purshia tridentata*) ($r^2 = 0.89$, Basile and Hutchings 1966). However, low standard errors of estimate (table 1) indicate diameter measurements can give precise estimates of jojoba twig weight. Utilization percentages can easily be calculated by measuring maximum diameter of browsed and unbrowsed current year's twigs to determine total yield and by measuring diameters of browsed twigs at the point of browsing to determine weight removed by browsing. These measurements should be taken at the end of the grazing period before regrowth occurs. In developing and using diameter-weight relationships of jojoba it should be remembered that leaf fall may occur with summer drought (Gentry 1958). Also, flushes of vegetative growth associated with significant precipitation occur in the spring and summer (Haase 1976). Jojoba utilization should be measured after significant growth and use periods.

Percentage of number of twigs browsed tended to be lower than percent utilization by weight for current year's twigs, but was slightly higher than weight utilization for total twigs on two moderately grazed areas (fig. 2). Percent browsed twigs would tend to underestimate weight utilization of current year's twigs and overestimate utilization of total twigs, especially at high utilization levels. There was high variation in weight utilization among branches with similar percentages of twigs browsed. However, mean percent utilization by weight and by numbers of browsed stems was generally statistically similar for both areas (table 3). A plot of the variance of weight utilization in relation to sample size indicates that for these moderately-grazed shrubs, at least two branch samples from each of at least 18 shrubs, with 10 or more twigs per branch, were needed to obtain a good estimate of utilization.

One major problem in estimating utilization of jojoba is that of determining how much current

HORRELL

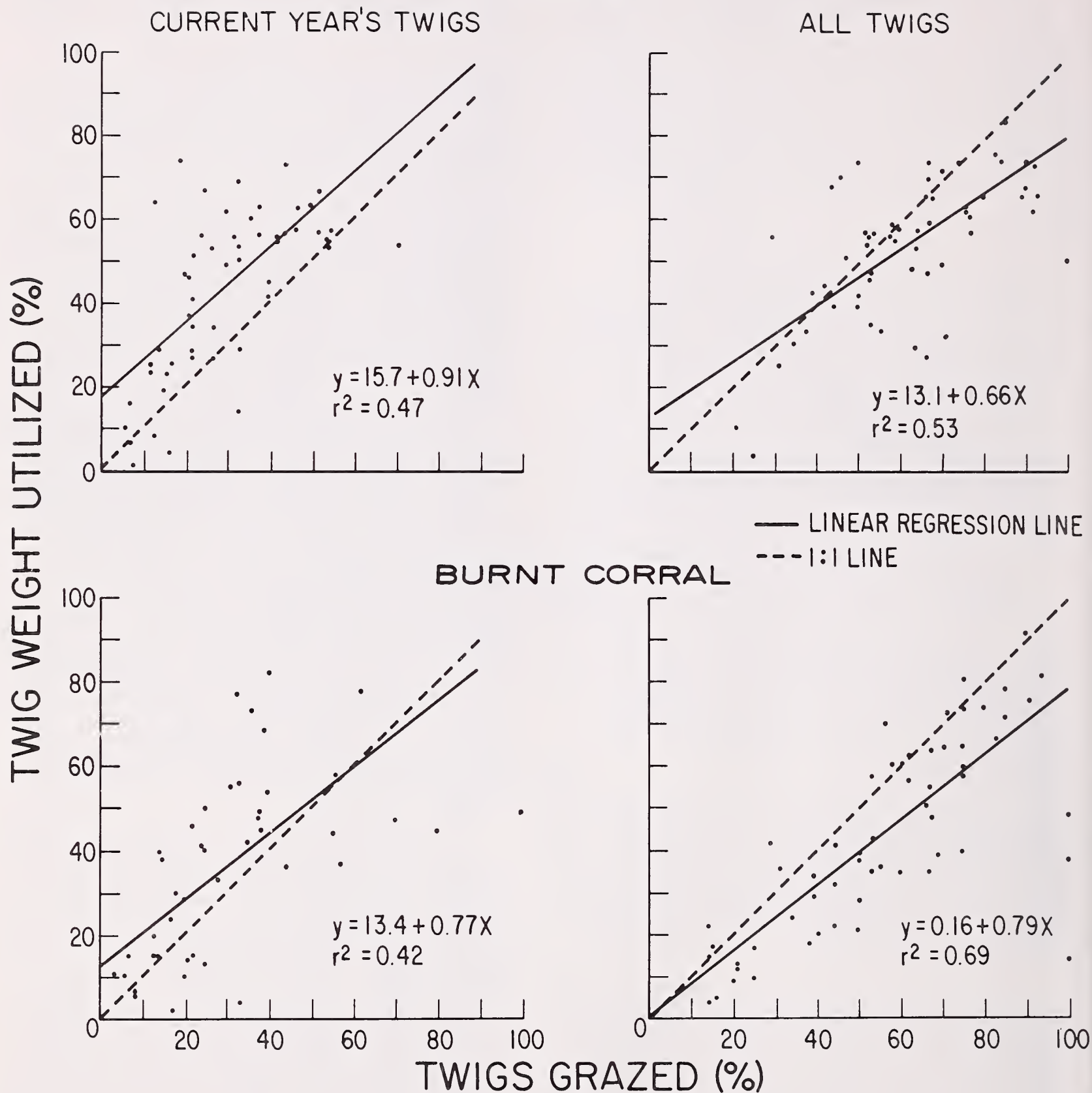


Figure 2.--Percent weight of jojoba utilized in relation to percent twigs browsed for moderately-grazed shrubs at two areas in southern Arizona.

Table 3.--Percent twigs browsed and percent weight utilized for moderately-grazed jojoba on two areas in southern Arizona.

Utilization estimate	Current year's twigs		All twigs with diameter <3 mm	
	Horrell	Burnt Corral	Horrell	Burnt Corral
Twigs browsed (%)	27.2b	23.8a	59.1a	54.8a
Weight utilized (%)	39.a	29.4a	52.0a	42.7a

Means in columns followed by the same letter are not significantly different ($p \leq 0.05$).

year's growth has actually been removed by grazing animals during a grazing period when some previous year's growth has been taken. It is not possible to determine how much current year's growth is associated with previous years' stems that have been removed in the current year. It was observed that cattle may graze previous years' twigs before all current year's twigs have been browsed.

Intensity of grazing affects the distribution of leaves and twigs with respect to depth in the jojoba shrub canopy (fig. 3). Most leaves and twigs are concentrated between 10 to 30 cm deep in the canopy. However, lightly grazed shrubs (< 10% utilization) had leaves and twigs more evenly distributed in the canopy than heavily-grazed ($\geq 80\%$ utilization) and moderately-grazed (40-50% utilization) shrubs. As grazing intensity increases, twigs and leaves are concentrated at a shallower depth in the shrub canopy. Peak numbers of twigs and leaves occurred at depths of 30, 25 and 20-cm into the canopy for lightly, moderately, and heavily-grazed shrubs, respectively. Although moderately and heavily-grazed shrubs were smaller in size, they had as many or more current and previous year's twigs and leaf pairs per branch as did lightly-grazed shrubs (table 4). Browsing jojoba evidently stimulates twig growth from lateral dormant buds as occurs with many other shrubs (Garrison 1971) and results in a hedged appearance. Mills and Foster (1982) have cited observations that jojoba is not only tolerant of pruning but that pruning stimulates vegetative growth. The greater leaf pair numbers of moderately than lightly-grazed shrubs in this

study indicate that new growth stimulated by twig removal compensates for loss of twigs as suggested by Mills and Foster (1982). Browsing does not necessarily reduce photosynthetic capacity but may actually increase it by stimulating twig and leaf production on a per branch basis. Moderate grazing resulted in highest photosynthetic biomass per branch as indicated by highest numbers of leaf pairs compared to lightly and heavily-grazed shrubs.

Since successive weather conditions that produce high seed germination and seedling survival are rare (Mills and Foster 1982) continuing seed production over many years is necessary to ensure stand renewal and stability of jojoba. Thus, the effects of browsing on jojoba seed production is of concern. Gentry (1958) cites examples of high seed production of shrubs that were pruned and irrigated and also lack of fruit development in wild plants severely browsed by cattle. Ruyle and Roundy (1985) found jojoba shrubs continuously grazed for at least 30 years were smaller in size than ungrazed shrubs and that jojoba cover was less but shrub density similar for adjacent grazed and ungrazed stands. Jojoba is thought to have a long life span (Gentry 1958) and, theoretically, each female plant would only have to produce two successful seedlings over its lifetime to maintain a stable population (Mills and Foster 1982). Because of jojoba's longevity and the infrequency of weather conditions for high seedling survival, the effects of reduced seed production or seed removal on jojoba stand renewal is uncertain and can only be determined

Table 4.--Total numbers of stems and leaf pairs per branch for jojoba under different grazing intensities.

Grazing Intensity	Weight utilized (%)	Leaf pairs	Stems		Total
			Current years (Number/Branch)	Previous years	
Light	≤ 10	95.2b	30.4a	19.0b	48.3b
Moderate	40-50	146.7a	37.9a	27.6a	65.6a
Heavy	≤ 80	92.7b	29.4a	28.9a	58.9ab

Means in columns followed by the same letter are not significantly different ($p \leq 0.05$) by Duncan's multiple range test.

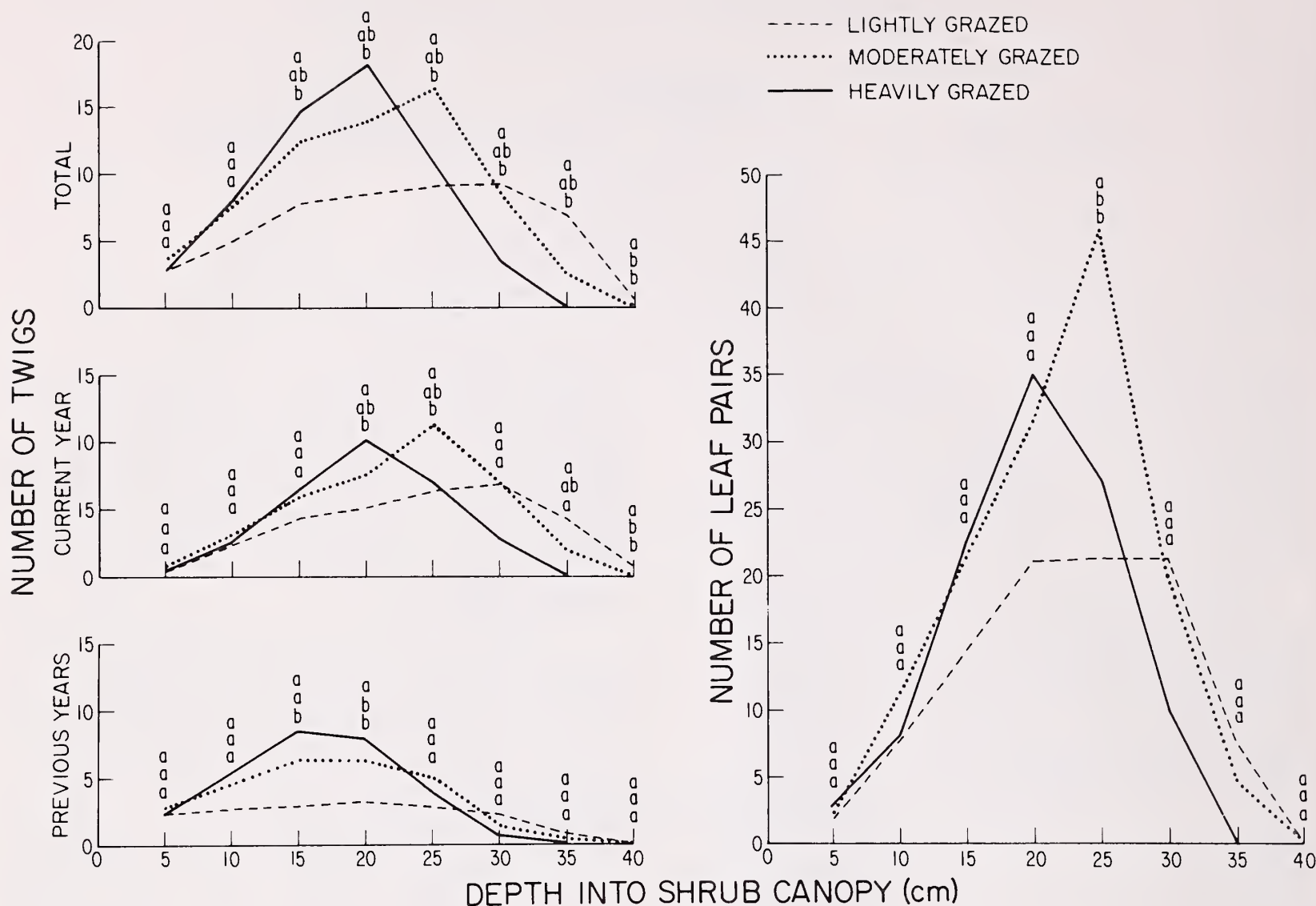


Figure 3.--Numbers of stems and leaf pairs in relation to depth into the canopy for lightly, moderately, and heavily-grazed jojoba in southern Arizona. Letters above apply to points below in order and any points having the same letter are not significantly different ($p < 0.05$) at that depth by Duncan's multiple range test.

in long-term studies (Mills and Foster 1982). Given the high tolerance of jojoba to grazing and its ability to maintain high amounts of photosynthetic tissue when grazed, practical guidelines for its management might be better concerned with monitoring shrub size than the more time-consuming process of estimating utilization. Maximum and minimum crown diameter and height of marked shrubs could be measured on a yearly basis. A gradual increase in shrub size would indicate that the shrub has a positive energy budget and is able to maintain itself and expand under the present management. Decreases in shrub size not associated with die-back during very dry periods (Gentry 1958) would indicate overgrazing.

More definitive guidelines for grazing management will be available with continued research on jojoba response to defoliation. Methods of estimating yield and utilization presented in this study will be useful in

conducting this research and in estimating utilization more accurately than by counting browsed twigs. In the meantime, management based on maintaining or gradually increasing shrub size relative to the potential for a given site may be an appropriate alternative to managing for a given level of utilization.

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Resumen.--Pesos de ramitas de jojoba (*Simmondsia chinensis*) de tres sitios en Arizona sur fueron correlacionados por alta medida con la cuadra del diámetro de internodio de ramitas. Medidas de diámetro se pueden usar para estimar la producción de este arbusto importante y su utilización por ganadería y fauna silvestre. Estimaciones de utilización apoyo del el porcentaje de ramitas ramoneadas puede ser inexacto.

248 El Cultivo de la Jojoba en el Noroeste de Mexico,¹

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Resumen.--Investigaciones antepasados han indicado que hay un gran potencial para la producción y comercialización de jojoba. Estudios ecológicos han puesto su énfasis sobre la tecnología para producción. Programas de investigaciones de CIANO buscan a descubrir clones de jojoba que tengan características favorable para producción y su propagación.

INTRODUCCION

Son pocas las especies silvestres que en los últimos quince años hayan tenido tanta promoción e investigación para lograr su domesticación y aprovechamiento del recurso silvestre, como ha sucedido con la jojoba (*Simmondsia chinensis*). Esta especie silvestre del Desierto Sonorense se distribuye en los estados de Sonora y Baja California en México y Arizona y California en Estados Unidos. Sus características principales por las que ha promovido tanto interés, son su capacidad de desarrollo y sobrevivir bajo condiciones prolongadas de sequía, y por las características tan peculiares de la cera líquida que se acumula en sus semillas.

La jojoba es una planta dioica, su raíz es pibotante y tiene un crecimiento rápido durante la germinación; alcanza a profundizar más de 4 m en condiciones favorables. La planta está formada por varias ramas que nacen de la corona de la raíz. Es un arbusto siempre verde de formas variadas, tipificándose en erectas, estéricas y rastreras. Las hojas son coriáceas, de forma oblonga y dispuestas en pares. Las flores estaminadas son por lo general solitarias que crecen en las axilas de hojas en crecimiento anual, al igual que las flores pistiladas, sólo que éstas se presentan en racimos.

El fruto es una cápsula generalmente dehiscente, y en ésta se desarrollan de una a tres semillas que contienen en los cotiledones de 30 a 60 por ciento de cera líquida, fácilmente extractable con prensas de uso convencional.

Usos de la Cera de Jojoba

A partir de diciembre de 1970, fecha en que entró en efecto la prohibición de importaciones de aceite de ballena a los Estados Unidos, se inició investigación de posibles sustitutos (Gisser, 1975). Hasta esta fecha, Estados Unidos importó un promedio anual de 18 000 toneladas de aceite de ballena, la mitad se utilizó con adiciones de azufre, para fluidos de transmisiones, lubricantes de diferenciales y grasas (Hotten, 1972). El aceite de ballena se utilizaba también en procesos de curtiduría, lubricantes de mecanismos de relojería, en la fabricación de cosméticos, producción de ceras y ácidos grasos (Frankel, 1976). Posteriormente a la prohibición de importaciones de Aceite de Ballena, se abatieron las reservas disponibles y se desarrollaron algunos sustitutos obtenidos de grasas de cerdos, ésteres de metilo y productos sintéticos derivados de ésteres de alto peso molecular actualmente en uso (Thomson, 1972).

La cera de jojoba tiene características similares que el aceite de ballena (Greene y Foster, 1938). Puede ser utilizado como sustituto de éste, siempre y cuando su precio sea competitivo con los sustitutos actualmente utilizados.

Entre algunos de los usos potenciales de la cera de jojoba se mencionan: con adiciones de azufre, como aditivo de lubricantes, como componente en tintas de imprenta (Kester, 1948).

Mediante la hidrogenación de la cera de jojoba, se produce cera de excelente dureza con un punto de fusión de 70°C, por lo que se contempla como sustituto de otras ceras vegetales como la candelilla y carnauba (Knoepfler, 1958). La cera de jojoba tiene uso potencial como cera abrillantadora para muebles, pisos y automoviles. Así como en la producción de desinfectantes, surfactantes, emulsificantes, resinas, plastificantes (Kester, 1948).

No obstante la diversidad de aplicaciones que tiene la cera de jojoba, ésta se ha utilizado

¹ Ponencia presentada en la Reunión Sobre Manejo de Plantas en Zonas Áridas. Saltillo, Coahuila, México. Febrero 18-22, 1985.

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exclusivamente en la elaboración de cosméticos, dado su alto precio que sólo la industria de cosméticos puede sufragar. El galón de jojoba llegó a cotizarse en 200 Dólares en 1981 (Kato y Kuhimoto, 1982); actualmente fluctúa entre \$30.00 y \$40.00 Dls/Galón.

Se considera que la superficie de jojoba actualmente en cultivo de aproximadamente 20,000 ha, es suficiente para abastecer la demanda actual (Thomson, 1982). Por lo tanto, es necesario incrementar la productividad de la jojoba cultivada y reducir costos de producción para que ésta sea competitiva con los actuales sustitutos del Aceite de Ballena o como lubricante de uso común. Dado la constante disminución de las reservas de petróleo y el constante incremento en el precio de éste y sus derivados como los lubricantes, es de esperarse que la jojoba tenga en el futuro una demanda extensiva en este campo.

ANTECEDENTES

En 1972 se inició la investigación sobre jojoba en CIANO, el enfoque fue inicialmente probar su adaptación fuera de su ambiente natural. En estos primeros trabajos se recolectó semilla de diferentes localidades en Sonora y Baja California Sur. De la primer siembra se obtuvieron los primeros datos sobre fenología y primeros frutos en 1976. La investigación subsiguiente en CIANO se encaminó a desarrollar tecnología de producción enfocada en fechas de siembra, densidad de plantación, podas y conducción de plantas, fertilización y evaluación de la dinámica insectil en jojoba cultivada, así como la insidencia de enfermedades. Asimismo, se realizaron trabajos para determinar época y cantidad de riegos.

Paquete Tecnológico

Establecimiento de Plantación: La jojoba puede establecerse mediante la siembra directa de la semilla en el campo o la siembra inicial en macetas para posterior trasplante. El primer método resulta ser el más práctico para las regiones donde hay disponibilidad de agua de riego. El trasplante de macetas requiere del desarrollo inicial de vivero y posterior trasplante, lo que incrementa los costos de establecimiento considerablemente. Este método es recomendado para establecer plantaciones de temporal o reforestaciones en sitios silvestres.

Fecha de Siembra: La semilla de jojoba germina fácilmente a temperaturas entre 21 a 29°C. En la Costa de Hermosillo se ha logrado emergencia de plantas de semillas sembradas en todos los meses del año. Sin embargo, las plantas obtenidas en el otoño o invierno, corren gran riesgo de ser aniquiladas por heladas. Se recomienda realizar la siembra o trasplante inmediatamente después del período de heladas.

Fertilización: Los diferentes tratamientos de fertilización nitrogenada de hasta 240 kg de

N/ha, no mostraron efecto positivo en la producción de semilla de jojoba. Se considera que el nivel de nutrientes disponible en los suelos de la Costa de Hermosillo es suficiente para llenar los requerimientos de la jojoba. No obstante, es de esperar que estos nutrientes con el tiempo sean redicidos y se presenten síntomas de deficiencia.

Plagas y Enfermedades: Muestreos sistemáticos efectuados en jojoba silvestre con jojoba cultivada con el objeto de estudiar la dinámica de la fauna insectil, indican la presencia de varias especies. No obstante, la única que se considera hasta la fecha como posible plaga es Homalodisca lacerta de la familia Cicadellidae, que se presenta en mayor abundancia de octubre a abril. Esta especie se congrega en las plantas de jojoba dejando excrementos sobre el follaje, sobre los que posteriormente desarrolla fumagina y provoca defoliaciones (González V. 1979). De los microorganismos causantes de enfermedades se han detectado a Fusarium oxysporum causando decoloraciones de tejido vascular y marchitez; Macrophomina phaseoli, causando pudrición radicular; Alternaria sp. provocando defoliación y Phymatotrichum omnivorum, causando pudrición de raíz (Romo et al. 1980). En octubre de 1984 se presentó una defoliación severa en varios lotes comerciales, presumiéndose que fue causada por Cercospora sp. Esta última, por la severidad del daño, puede convertirse en un problema serio que requiere de investigación para prevenir futuras infecciones.

Riego: Los trabajos encaminados a determinar la época y cantidad óptima de agua de riego, han indicado que el mejor desarrollo vegetativo se logra con 57 cm anuales repartidos en los meses de diciembre a abril. No se ha determinado aún la cantidad mínima óptima de riego para lograr la máxima producción de semilla, debido a la alta heterogeneidad encontrada en las plantas utilizadas. Actualmente se ha establecido un lote clonal para reducir la variabilidad en producción y determinar la lámina mínima (Ortiz, 1980). Ensayos preliminares indican la factibilidad de obtener altos rendimientos de semilla con 35-40 cm de lámina de riego.

Cosecha: La mayor parte de la cosecha de jojoba se realiza en forma manual. Sólo 100 ha en la Costa de Hermosillo son cosechadas mecánicamente con una cosechadora de uva industrial ajustada y que tiene una eficiencia poco aceptable, además de dañar demasiado a la planta.

La cosecha manual es laboriosa, se cosechan aproximadamente 6 kg de semilla limpia y seca por jornal. En una plantación en producción, la recolección representa la mayor parte del costo de producción.

Durante el ciclo 1984 se evaluó comercialmente a iniciativa del productor un sistema de recolección mediante una malla de plástico extendida en la base y a lo largo de las hileras de plantas. Este sistema, según reporta el propietario de la finca logra una eficiencia de hasta 40 kg de semilla limpia por jornal.

Plantaciones Comerciales

A partir de 1977 se iniciaron las plantaciones comerciales en la Costa de Hermosillo, Sonora. Para éstas se utilizó tanto el sistema de siembra directa como transplante en macetas, utilizándose semilla proveniente de poblaciones silvestres cercanas. Las primeras plantaciones establecidas en terrenos de pequeños propietarios fueron financiadas con recursos propios a excepción de 35 ha financiadas por la Comisión Nacional de Zonas Áridas. En la actualidad existen aproximadamente 800 ha de riego y 2300 de temporal. Estas últimas fueron establecidas a partir de 1980 en terrenos ejidales financiados por COPLAMAR.

En 1980 se inició la primera cosecha comercial de jojoba en la Costa de Hermosillo, lográndose rendimientos de 30 a 160 kg/ha. En años subsiguientes los rendimientos se incrementaron hasta promediar de 300 a 1800 kg/ha en 1983. En 1984, la producción se redujo considerablemente por daño de heladas, lo mismo ocurrirá este año ya que la floración y botones florales fueron severamente dañados el 31 de enero pasado por temperaturas de -4°C .

De las plantaciones establecidas bajo temporal no se ha reportado producción aún. Por las condiciones de sequía en que generalmente se encuentran estas plantas, se reporta una condición de plantas de mala a regular.

Se considera que las plantaciones de riego han sido económicamente rentables, inclusive en aquellas en que se han tenido bajos rendimientos, dado que la producción alcanzó valores de \$500,000.00 M.N./tonelada en 1981 y de \$700,000.00 M.N. a 1 Millón en años posteriores, no obstante hubo problemas de comercialización. En términos reales, los productores no venden su semilla, sino que la procesan y transforman en cera, siendo éste el producto final. Esta se cotiza en Dólares/Galón y se exporta principalmente a Estados Unidos, de donde posteriormente se exporta a otros países.

En los últimos años, el interés de agricultores privados por establecer nuevas plantaciones de jojoba, ha decrecido considerablemente. Esto es debido a la inseguridad de la comercialización e inestabilidad de la producción. Por otra parte, el apoyo e interés mostrado por algunas dependencias oficiales en la década pasada, también se ha aminorado.

Enfoque Actual y Últimos Avances de la Investigación

Se calcula que existe un potencial de cultivo de jojoba de aproximadamente 20,000 en el Noreste de México, para abastecer la demanda nacional y para exportación a otros países. De acuerdo a la información proporcionada por los productores sonorenses, el costo de producción de éstos es aproximadamente 43% del costo en Arizona, dando un buen margen para competir en un futuro mercado

internacional. Se considera que al estabilizarse el precio de la cera de jojoba y ésta se utilice como lubricante más extensivamente, habrá demanda por tecnología de producción para jojoba cultivada y aprovechamiento de jojoba silvestre. Nuestro objetivo es tomar la delantera y prever las futuras necesidades de tecnología.

Jojoba Cultivada

El enfoque actual del programa de investigación de CIANO, es desarrollar cultivares de jojoba mediante la selección de plantas altamente productivas y su propagación vegetativa para formación de clones. Paralelamente se continúan trabajos sobre productividad con los clones ya disponibles con el objeto de desarrollar la tecnología adecuada para la expresión de su potencial genético.

La investigación que se realiza en el Campo Agrícola Experimental de la Costa de Hermosillo, está enfocada a desarrollar tecnología de producción bajo riego, dado que en esta zona la precipitación es insuficiente. En la región serrana de Sonora donde ocurren isoyetas de 300 mm o superiores, se tienen lotes fenológicos para estudiar adaptación para temporal.

Jojoba Silvestre

En la Costa de Ensenada, el Programa de Investigación está enfocado al aprovechamiento de las poblaciones silvestres. Los trabajos sobre manejo realizados en las poblaciones silvestres de la Costa de Ensenada incluyen: Reforestación con clones seleccionados, desmontes selectivos, captación de agua, estudios sobre polinización y fenología. De estos trabajos, únicamente hay resultados con respecto al uso de microcuencas para captación de humedad que indican preliminarmente un incremento al doble de la producción del testigo. Los demás proyectos están por iniciarse o iniciados apenas el ciclo pasado.

Desarrollo de Variedades Clonales en la Costa de Hermosillo

La jojoba es una especie dióica por lo que su reproducción es obligadamente halogámica, lo que genera una amplia gama de genotipos, dando lugar a plantas con características de forma y productividad variada. En el CAECH se ha caracterizado la producción individual por planta durante 8 años de cosecha y de esta forma seleccionando las plantas de mayor productividad y de más consistencia (Cuadro 1). Estas plantas fueron propagadas vegetativamente mediante el enraizamiento de brotes terminales (Hogan et al., 1978) y establecidas en un ensayo de rendimiento de clones en el mes de mayo de 1981. Actualmente estas plantas tienen ya 3 años de crecimiento en el campo y han producido dos cosechas.

CUADRO 1. PRODUCCION DE SEMILLA Y CERA DE 14 PLANTAS DE JOJOBA SELECCIONADAS.

CLAVE DE PLANTA	1977	1978	1979	1980	CONTENIDO DE CERA
LA7A	225	777	1000	2135	39.2
LA12D	116	817	605	2125	47.0
LA13B	499	920	1150	1620	45.7
LA27H	102	424	1325	1530	41.4
LA28C	370	502	660	750	37.7
LA36G	459	932	655	1170	41.8
LA39F	674	755	120	820	37.9
LA49H	33	235	1000	1025	47.6
LA24E	369	680	565	1030	-
LB11E	145	550	240	1255	41.2
LB24B	229	907	515	1310	37.9
LB33E	-	997	980	465	41.2
LB51C	30	296	400	1075	39.7
LB57F	10	302	635	1280	39.3

Rendimiento de Clones

Durante el primer año de crecimiento, la producción de semilla fue escasa, sólo una cuantas semillas por planta. La primera cosecha significativa de estos clones fue en el segundo año de crecimiento, teniéndose un promedio general de 130 g. El promedio de producción del mejor clon en este año fue de 314 g (Cuadro 2). Los clones superaron por un año en precocidad a cosecha a las plantas propagadas por semilla.

Durante el tercer año de crecimiento, los clones de jojoba incrementaron su rendimiento promedio a 578 g, que sobrepasa un 30% el rendimiento de las plantas propagadas por semilla (primer cosecha). El mejor clon en ese año rindió 777 g/planta, superando a las plantas propagadas por semilla en 55% (Cuadro 1).

Variabilidad

Al propagarse vegetativamente las plantas de jojoba muestran poca variabilidad en cuanto a su forma de planta o hábito de crecimiento. Sin embargo, se observó gran variabilidad en el rendimiento de semilla entre plantas de un mismo clon (Cuadro 2). Durante la primera cosecha el C.V. general fue de 75% y 62% en la segunda cosecha. En el Cuadro 2 se indica la variación observada para cada clon.

Selección y Evaluación de Plantas Masculinas para Polinización

Inicialmente la selección de machos para polinización se realizaba básicamente en función del vigor de la planta y de su período de polinización que fuera coincidente con la floración de las plantas femeninas, ya que el período de floración de éstas es variable de 3 a 7 semanas. Ultimamente en CIANO (Morales, 1984), hemos podido

caracterizar plantas masculinas en función de su capacidad combinatoria de acuerdo al por ciento de amarre de fruto que se obtiene. Estos trabajos se han realizado mediante cruzamientos controlados de plantas masculinas y femeninas y evaluando la frecuencia de frutos logrados según el origen genético del polen. Estos trabajos han indicado que existe una influencia altamente significativa del macho polinizador para lograr el máximo por ciento de amarre de fruto.

En base a estos resultados creemos que la variabilidad en rendimiento entre plantas de un mismo clon se debe en parte a la variabilidad genética de los machos polinizadores. (Los machos polinizadores de los clones provienen de semilla). El potencial genético de varios clones de plantas femeninas de jojoba puede ser expresado utilizando al polinizador con la mejor capacidad combinatoria general.

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CUADRO 2. RENDIMIENTO DE SEMILLA DE JOJOBA Y SU VARIABILIDAD EN CLONES Y PLANTAS PROPAGADAS POR SEMILLA EN DOS AÑOS DE COSECHA.

IDENT.	1983		1984	
	PROMEDIO gr/PLANTA	C.V. (%)	PROMEDIO gr/PLANTA	C.V. (%)
LA7A	83	60	663	44
LA12D	153	59	603	38
LA13B	123	40	777	50
LA27H	73	112	703	107
LA28C	230	2	766	22
LA36G	38	25	391	58
LA39F	188	57	736	68
LA49H	122	134	655	70
LA24E	164	44	674	66
LB24B	314	28	560	19
LB33E	265	62	540	53
LB51C	19	13	228	82
LB57F	59	138	471	71
SC3	53	59	409	108
PLANTAS DE SEMILLA	-	-	429	77
PROMEDIO GENERAL	138	75	578	62%

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Abstract.--Past research has indicated that there is a great potential for production and commercialization of jojoba. Ecological studies have placed their emphasis on production technology. Current research programs (CIANO) seek to find clones which possess favorable production and propagation characteristics.

245 Administration of Jojoba Harvesting on National Forest Lands¹

Donald A. Van Driel²

Abstract. Increased demand for the collection of jojoba bean on National Forest lands resulted in an environmental study to evaluate the effects of large scale harvesting; the effects were minimal. Conclusions after several years of harvesting were that litter was the only administrative problem and there were no adverse environmental effects.

It is an honor and a privilege to speak to this international group on administration of jojoba plants on Federal lands in Arizona.

The Tonto National Forest is located in the semiarid mountainous region of central Arizona. The Tonto is divided into six Ranger Districts, but only four contain commercial stands of jojoba.

Jojoba bean collection has occurred in Arizona since the late 1920's. The majority of the jojoba producing land in central Arizona is located on National Forest lands. Although bean collection on National Forests has occurred for several decades, it was not until the early 1970's that demand resulted in a need to look at the environmental effects of high harvest levels on the jojoba plants and their environment. After the First International Conference on Jojoba, which was held in Tucson, Arizona in 1972, the large scale interest in bean collection and oil production occurred. No significant effort was made to regulate bean collection on National Forest lands until 1978. Records indicated that in that year permits were issued for the sale of 14,000 pounds of beans. Sales increased to a record year in 1982 where 368,925 pounds were sold. Since that time sales have been considerably less due to low prices and poor crops.

In 1978 an environmental analysis study was made which evaluated and predicted impacts resulting from the large scale harvesting of jojoba on National Forest lands. The following is a brief look at how this process evolved.

Evaluation criteria was established, identifying the various points that were critical in the development of a jojoba harvesting operation. These criteria points would be used to weigh the various alternatives against the selection of the best

method of harvest. First, the harvest operation must be consistent with existing multiple use guidelines. (These guidelines are found in an approved Multiple Use Plan which has determined what activities and uses are acceptable for a given land area.) Secondly, the operation must meet the needs of each Ranger District and the public. Next, the harvest of jojoba beans must ensure the protection of the plant and its associated environment. Last, the agency must be able to adequately administer the program.

The impact of harvesting jojoba was analyzed relative to key social, economic, and resource concerns. What effect would bean collection have on future reproduction of new plants? Would adequate beans be left to ensure plant propagation and how would the agency monitor this impact? How much soil compaction results during harvest operations? Or will harvesting create soil churning? Will either of these soil conditions create long range adverse environmental impacts or are they short term? What effect will harvesting have on wildlife? The pocket mouse is solely dependent on the jojoba bean as a food source--will this animal possibly be displaced by jojoba harvesting in certain areas? Deer and javalina utilize both the bean and forage. What effect will the additional traffic on dirt roads have on air quality? Will trampling by harvesters increase soil movement and decrease water quality? What effect will this trampling have on range forage production? Are there any threatened and endangered plants or wildlife in the harvest area? Will they be impacted? Will the harvesting operations increase the amount of litter and trash in these dispersed areas? How much will it cost to operate and administer a jojoba harvesting operation? Will the program pay it's way? What are the positive and negative social and economic concerns?

As these questions were addressed in the environmental assessment process, several alternatives developed. The Forest Service could choose to not encourage any harvesting of jojoba on Federal lands. Persons found collecting beans on the forest would be cited. Areas of concentrated jojoba stands could be broken into blocks and contracts awarded for collection of beans by commercial harvesters. Large areas could be open for jojoba bean collection

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and sales would be made over-the-counter to individuals. A combination of over-the-counter and contract sales by designated areas could be made.

The combination of individual and commercial sales best met the objectives established in the evaluation criteria and provided the most opportunities for mitigation of any adverse impacts to the affected resources. This alternative also maximized the social and economic benefits by making permits available to all segments of the population. This alternative thus became the preferred alternative in the environmental assessment document.

Although no significant unacceptable impacts were surfaced during the evaluation assessment process, several problem areas, particularly in the administration of a large scale jojoba harvesting program were identified. Due to the generally moderate to low plant densities on the Cave Creek, Globe, and Mesa Ranger Districts and the anticipated high demand due to the proximity of these districts to population centers, it was determined that only over-the-counter, personal sales would be made on these three districts. The Tonto Basin District would make both over-the-counter personal use sales and commercial contract sales. Higher plant densities exist on this district and the areas are more remote.

Off-road travel was prohibited in all harvest areas to minimize soil disturbance and plant damage. No mechanized harvesting would be permitted to reduce the likelihood of severe damage to the jojoba plant itself.

Wilderness areas were excluded from the permitted harvesting areas.

Permits would be available after July 15 of each year. Permit termination dates would vary with the size of the sale--small sales would have a short permit period approximately two weeks per 100 pounds. Larger sales would be permitted a longer time period. Permit durations would also be adjusted depending on the number of persons picking per permit. For example, if the permittee planned on harvesting with a crew of 10 or 15, a 100-pound permit may expire in one week instead of the normal two weeks.

Most districts did not have the manpower to adequately administer the ground harvesting activities. Field personnel are needed to insure pickers are authorized by permit and to enforce the no off-road travel and no mechanized harvesting requirements of the permit. In some cases, large camps developed and agency personnel were needed to ensure impacted areas were cleaned up and equipment removed from the forest at the termination of the permit.

The picking season was initially established from July 15 to December 31. After a few seasons of picking, this time period was reduced to July 15 to September 15. The two major factors contributing to this shortening of the harvest period were: several years of high demand coupled with high product value resulted in a more complete harvest

than desirable and in some areas no beans were left for plant propagation and wildlife forage. Due to the Federal Government's budget process most districts also lost the majority of administrative manpower by October 1, when the seasonal workforce is terminated. Typically this results in a 50% reduction in field-going personnel to administer the permits.

Information signs, describing the permit requirement and where permits may be obtained were posted at all major entrance points in English and Spanish. Even with this signing, districts experienced moderate to heavy picking prior to July 15.

Compliance patrols revealed that most people had obtained the required permit. However an Arizona Jojoba Association comparison of total pounds of beans sold by the Forest Service to estimates of total pounds purchased from people picking on Forest Service lands, indicate that as much as five times the amount sold are actually picked from National Forest lands. The problem again is lack of administrative manpower and large harvest areas.

During years when demand and price are high, harvesting pressures occur as long as the market will last. Jojoba prices were particularly high in 1981 and illegal picking occurred throughout the winter. In most cases this late season activity is conducted by organized pickers working independently or for a contractor and they are aware they are in violation of the regulations. These pickers established camps, hidden from the normal flow of traffic and, when approached would run and hide to avoid contact with a forest officer. Again, it is difficult to control this type of activity due to the remoteness of the harvest sites, large number of acres involved, and the lack of manpower.

Trash has become a large problem on National Forest lands. Although the jojoba pickers do not create all our trash problems, they do compound the problem. Most trash resulting from harvest activities is located in more remote areas than other user trash. Picking camps are by far the largest problem. In many cases cars, couches, chairs, tables, and other miscellaneous trash is left behind. Day picker trash most commonly include paper, cans, and bottles. Regular cleanup crews do not collect trash from these remote areas which are managed as "pack in-pack out". Thus the trash is scattered by wind and animals, creating an even larger impact.

It is not uncommon for a large scale commercial organization to supply the money and have numerous individuals come in to buy a personal use permit. The organization will then bring in many hired pickers to work on each of the personal use permits. The commercial areas were established in blocks of land and sold on a bid basis. The individual sale areas were open for many permittees to utilize the same site. This resulted in areas that had been designated for personal use being harvested more intensely than planned. Generally the commercial operators were more thorough in their collection of beans than the individual pickers. The end result was fewer or, in the most severe cases, no beans

were left for individuals as well as an overpick from the standpoint of regeneration or wildlife needs.

Harvest of jojoba beans outside the established season created some rather significant impacts to the jojoba plants. The pickers would wait for the beans to fall off the bushes then prune the bushes back so that the beans could be collected from the ground. In most cases the pruning is severe and impacts the ability of the plant to produce maximum livestock and wildlife forage as well as beans during the next growing season.

During years when the demand and price are high, the impacts and illegal activities are also

high. During the last several years, administrative problems have been relatively low as a result of both low prices and poor crops. This can also be a result of commercial jojoba farms that are just beginning production.

In conclusion there will be administrative problems associated with the harvesting of jojoba beans, but with the exception of litter, most are not common problems or considered critical. Therefore it is concluded that jojoba beans can be hand harvested annually from native stands with little or no adverse effects on the environment. This conclusion is based on a limited amount of time and knowledge and should not be considered absolute.

Resumen.--El crecimiento de la demanda para la colección de el frijol de jojoba en tierras de forestales nacionales ha resultado en un estudio ambiental para evaluar los efectos de recolección en escalas grande; los efectos fueron mínimo. Las conclusiones despues de varios anos de cosecha fueron problemas administrativas sobre basuda dejado al compo y los efectos ambiental no fueron adverso.

245 El Nopal (*Opuntia* spp) y su Utilizacion en Mexico¹

Facundo Barrientos Pérez²

Resumen.--El nopal (*Opuntia* spp.) es una planta abundante en México y presenta un gran polimorfismo, existiendo diferentes especies silvestres y cultivadas. Para los habitantes de las zonas desérticas y semidesérticas esta planta es muy importante, ya que se le puede utilizar directamente en la alimentación humana por sus frutos o por brotes tiernos de la planta y en la alimentación de ganado, principalmente cuando escasean otros forrajes, debido a la falta de humedad. Industrialmente también se le utiliza para manufacturar productos alimenticios y otros.

Debido a la variabilidad genética del material, a la presión selectiva natural y artificial, así como a la reproducción sexual y asexual es que existen diferentes tipos, los cuales prosperan en diferentes condiciones ambientales, algunos ampliamente distribuidos y abundantes como *Opuntia streptacantha* y *Opuntia leucotricha*, conocidos como nopal cardón y duraznillo respectivamente. Dichas especies se localizan principalmente en la zona Central Potosina Zacatecana, mencionada por Velázquez (1962), delimitándose 38,000 km² con nopal cardón, de los cuales se explotan alrededor del 50%. De duraznillo 45,000 km² con una explotación del 15% (Borja 1963).

Algunas zonas como Teotihuacán y otras del Edo. de Hidalgo son reconocidas por la calidad de los frutos que producen sus nopales, en particular la tuna blanca de *Opuntia amyclaea*. En Milpa Alta, D.F., se le ha dado impulso a la producción de nopal para verdura y se siembra especialmente con ese fin.

INTRODUCCION

El nopal (*Opuntia* spp.) es una planta nativa de México muy abundante, presenta diferentes formas en estado silvestre y cultivado que dan idea de su evolución y adaptación a diferentes condiciones de clima y suelo dentro del territorio nacional. Esta adaptación, así como la utilización de sus frutos y brotes en la alimentación humana y del ganado, además la elaboración de colorantes, han sido la razón de su importancia en México. En el pasado junto con el maíz y el maguey, fue la base para los primeros asentamientos humanos; en la actualidad y principalmente para los habitantes de las zonas desérticas y semidesérticas esta planta es importante en la alimentación humana y del ganado, en particular cuando escasean otros forrajes

debido a la falta de humedad; en el futuro se considera su importancia para contener la erosión del suelo e inclusive la regeneración del mismo; como alimento, fuente de energía y producción de colorantes naturales.

DISTRIBUCION

En México están representados dos subgéneros de *Opuntia* que son: *Cylindropuntia* y *Platyopuntia*, el primero con forma cilíndrica y el segundo con forma aplanada. Al subgénero *Platyopuntia* pertenecen los verdaderos nopales cuyos frutos se conocen como "tunas" cuando tienen sabor dulce y "xoconoxtiles" cuando tienen sabor ácido (Bravo, 1937).

En el subgénero *Platyopuntia* la clasificación es bastante difícil, debido al enorme polimorfismo determinado por la hibridación. Según Bravo (1937), las especies de este subgénero pueden ser rastreras si desarrollan al nivel del suelo, frutescentes cuando tienen un tallo del cual parten ramificaciones y por último arborescentes,

¹ Ponencia presentada en la Reunión Sobre Manejo de Plantas en Zonas Áridas. Saltillo, Coahuila, México. Febrero 18-22, 1985.

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cuando por lo general tienen un tallo cilíndrico desarrollado formado por cladodios viejos, tomando un aspecto característico.

La posibilidad de cruzamiento mediante una polinización entomófila es frecuente y con posterioridad a la caída de los frutos la diseminación de semillas por aves es posible, obteniéndose variación, la cual puede mantenerse a través de una reproducción vegetativa. Debido a la enorme variabilidad de esta planta hay especies que soportan las sequías más prolongadas, así como grandes precipitaciones (116 mm - 2000 mm), asimismo desarrollan desde el nivel del mar hasta los 2600 m.

La mayor abundancia de nopal se localiza en los estados de Zacatecas, Jalisco y Durango, dominando principalmente la especie Opuntia streptacantha y Opuntia leucotricha, conocidas como nopal cardón lo constituyen sus frutos y partes tiernas, empleados con fines alimenticios ya sea en la elaboración de dulces, bebidas alcohólicas y también como frutos de mesa.

Se han delimitado 38,000 km² con Opuntia streptacantha de los cuales se explotan alrededor del 50%. El nopal duraznillo se explota principalmente con fines ganaderos eliminando sus espinas. Se distribuye aproximadamente en una superficie de 45,000 km² de los cuales se explotan más o menos el 15% (Borja, 1963).

Los nopales tuneros cultivados tienen una distribución principal en los estados de San Luis Potosí, Zacatecas, Aguascalientes; extendiéndose hacia el Sur especialmente en los estados de Querétaro, Hidalgo, Puebla, Tlaxcala, México y Oaxaca.

ESPECIES Y VARIEDADES

Entre las especies tuneras se considera principalmente Opuntia amyclaea conocida como nopal de tuna blanca o de alfajayucan, esta planta se ha distribuido ampliamente en diferentes estados, siendo en Hidalgo en donde más se cultiva. Generalmente próxima a la distribución de ésta especie se encuentra Opuntia megacantha, conocida como tuna amarilla y de un tamaño bastante grande. Opuntia streptacantha o tuna cardona es de la cual se derivan productos como los llamados queso de tuna, melcocha, colonche, etc., esta especie también se emplea ampliamente como forraje y crece como antes se dijo, en condiciones silvestres. Un número de variedades bastante grandes con pocas espinas o ausencia de ellas, pertenecen a la especie Opuntia ficus indica.

Otras variedades que se utilizan en el Valle de México son: (Opuntia spp.) con frutos de un sabor agrio y que tienen un alto contenido de vitamina C y pectinas; con ellos se elaboran dulces, jaleas y condimentan comidas típicas. Otra especie bastante empleada es Opuntia robusta y se utiliza especialmente para complementar algunas bebidas, siendo su fruto bastante grande.

En general, todas estas especies y variedades presentan gran diversidad tanto en el tamaño y forma de sus tallos, como en el tamaño, forma y coloración de frutos.

PRACTICAS CULTURALES

La abundancia y las diferentes formas en que se encuentra el nopal al estado silvestre y cultivado, dan una idea de su evolución y adaptación a diferentes condiciones de clima y suelo, llegándose a la domesticación de algunos grupos que interesan al hombre por las características de sus frutos, brotes o por la potencialidad para derivar productos industriales.

Las prácticas de manejo de la producción y el cultivo también evolucionan desde ecosistemas dominados por especies silvestres, que bajo condiciones naturales el hombre obtiene los productos del nopal, pasando al huerto familiar y finalmente al estado de transición actual, en donde se puede comprobar que a través de la investigación BASICA ORIENTADA será posible experimentar y diseñar esquemas apropiados a las condiciones y necesidades de México.

López y colaboradores (1977), obtuvieron datos representativos de ecosistemas naturales de Opuntia streptacantha, reportan una densidad de 550 individuos de tamaño mayor que 1.50 m, con una producción de 2,557 kg de tuna descortezada por ha; 225 kg por ha de semilla, con 27.8 kg por ha de aceite; el número de frutos producido es de 85,250 con un equivalente de 232.5 kg de queso de tuna por ha. Se considera que por jornal se cosechan y descortezan 4,120 tunas, y se requieren 20.6 jornales por ha para la cosecha. La producción media estimada es de 155 frutos por planta, de 70 gramos por fruto, estimándose una producción de 5,967.5 kg de fruto sin descortezar por ha.

Según estimaciones de Cruz (1981), la superficie cultivada con nopal se aproxima a 6,000 hectáreas, con un rendimiento medio de 6.3 ton/ha, y una producción global de 37,800 toneladas. La superficie cultivada está cubierta con huertos familiares y a nivel comercial en superficies pequeñas con algunas mayores de 100 hectáreas, se obtiene la planta de huertos destinados a producción de fruta y generalmente de las podas anuales. Plantas con dos cladodios son depositados en cepas que varían en tamaño, es común la de 60 cm de largo, 60 cm de ancho y 50 cm de profundidad; se ha observado la ventaja de mezclar estiércol en una proporción de dos terceras partes del volumen de la tierra para llenar la cepa. Las distancias de plantación varían de 6 x 5 m, 6 x 4 m, 5 x 5, 5 x 4 y 4 x 4 las más comunes. Se practica poda principalmente para eliminar pencas mal dispuestas o dañadas. Uno de los principales problemas de estas plantaciones son las plagas que se combaten parcialmente.

La prospectiva de la producción futura indudablemente se apoyará en los conocimientos

basicos de genética, anatomía, morfología, fisiología y bioquímica de los órganos vegetativos y reproductivos de la planta.

Raiz

En general, el sistema radical es superficial y particularmente denso, las raíces muertas proporcionan grandes cantidades de materia orgánica al grado de cambiar el color de los horizontes superficiales de las plantaciones viejas. El parénquima cortical de las raíces gruesas permanece turgente y funciona como un almacén de agua. Las raíces secundarias mueren durante períodos largos de sequía y vuelven a crecer durante el período de lluvias.

Hernández y Barrientos (1978), estudiaron la distribución vertical y horizontal de raíces de *Opuntia amyclaea* Ten., en plantaciones con suelos de texturas diferentes: Migajón arenoso, migajón arcilloso y migajón arcillolimoso. Se encontró una alta correlación entre el peso fresco y seco de raíces menores y mayores de 2 mm de diámetro; por tanto es posible que los estudios de raíces en esta especie se realicen con el peso fresco. También hay correlación entre el número de raíces de los perfiles y el peso fresco de las mismas; en consecuencia para el estudio de raíces se considera conveniente emplear el método de "perfir o trinchera", ya que a igualdad de eficiencia es más sencillo. La distribución de raíces menores de 2 mm está influenciada por la extensión horizontal del sistema radical, la mayor cantidad de ellas se encontró entre 165 a 215 cm del tranco, y cuando había menor extensión entre 15 a 115 cm; a mayor extensión tales raíces son superficiales (0 a 20 cm). La mayor cantidad de las mayores de 2 mm se localizan entre 15 y 115 cm horizontalmente y entre 0 y 40 cm profundidad.

La información anterior permite el planteamiento de los siguientes temas: no hay necesidad de profundizar en la preparación del terreno para la plantación, más de 40 cm, no es necesario siquiera hacer cepas y menos aún deben ser profundas, ya que como se ha comprobado las paredes de las mismas pueden limitar el desarrollo lateral del sistema radical, bastará entonces con aflojar el terreno y darle pendiente para la captación de agua. Se ha encontrado que a medida que aumenta la densidad de plantación en nopal aumenta la producción de brotes y materia seca total, hasta la fecha se han probado densidades de 10,000 a 500,000 pl/ha sin observar decremento, bajo estas condiciones se observa que a medida que aumenta la densidad, las raíces profundizan más (Barrientos, 1972; Grajeda, 1978).

Tallo y Hojas

En el nopal es común observar hojas pequeñas durante el crecimiento activo del tallo, sin embargo en corto tiempo caen, por lo que en su ausencia el proceso fotosintético se realiza en las partes verdes de los tallos conocidos como

"cladodios". La forma aplanada de los cladodios, fue base para considerar el efecto de su orientación en la eficiencia fotosintética, su influencia en la producción de materia seca y en la producción y calidad de frutos. La mayor o menor captación de luz podría manifestarse por una elevación de la temperatura interna y aceleración de los procesos metabólicos. Los resultados confirmaron la hipótesis planteada y en los estudios de Becerra, Barrientos y Díaz (1976) se encontró que los cladodios orientados N-S (caras al E y O), elevan su temperatura con rapidez durante la mañana, la disminuyen al medio día y se vuelve a elevar hasta las 15 ó 16 horas para después bajar continuamente. Por otra parte, los cladodios con posición E-O elevan constantemente su temperatura hasta las 15 ó 16 horas. La temperatura de los cladodios es superior a la del aire durante el día, e inferior durante la noche. Durante la noche sin la presencia de luz se igualan las temperaturas de los cladodios con orientación N-S y E-O, lo que comprueba el efecto de la orientación en la captación de luz y elevación de la temperatura.

Materia Seca

El incremento de materia seca fue mayor en cladodios orientados N-S, con un promedio de 0.270 mg/cm²/hora; en tanto que los de E-O de 0.124 mg/cm²/hora. Al aumentar la radiación solar también aumentó la producción de materia seca. Los trabajos de Grajeda, Barrientos y Muñoz (1978), indican que los cladodios más eficientes por su producción de materia seca, son los que producen más brotes y son los que tienen 6 meses de edad en comparación con los de 3 y 12 meses (cuadro 1).

Frutos

Un mayor número de cladodios produjeron fruto cuando estuvieron orientados N-S, hubo mayor número de frutos por planta y por cladodio y un mayor contenido de sólidos solubles, en comparación con la orientación E-O (cuadro 2).

Desarrollo del Fruto

En los trabajos de Alvarado, Barrientos y Laksminarayana (1978), se encontró que las flores son protandrias y abren únicamente durante 24 horas. A las 17 semanas el fruto alcanzó 7.2 cm de longitud y 4.8 cm de diámetro, al momento del amarre ya se tenía el 65.3% de la longitud total del fruto y el 56.5% de su diámetro. Al momento del amarre la cáscara representó más del 95% del fruto y en las últimas 6 semanas el porcentaje de cáscara disminuyó hasta el 36%. Por otra parte, el corazón aumentó a partir de la décima semana en que se pudo separar.

Se encontró una curva climatérica de respiración, durante el desarrollo en la 13a. semana después del amarre y no después de la cosecha, por lo tanto el fruto de nopal se considera como un climatérico.

Cuadro 1. Valores promedio del incremento de materia seca en cladodios con diferente orientación
(Becerra, Barrientos y Díaz, 1975)

Experimento No.	Fecha de Realización	Orientación de Cladodios	Incremento de materia seca mg/cm ² /hora	Radiación total Cal/cm ²
1	14-X-74	Norte - Sur	0,332	553
		-----	0,211	
		Este-Oeste	0,089	
2	22-X-74	Norte - Sur	0,260	516
		-----	0,210	
		Este-Oeste	0,159	
3	7-XII-74	Norte - Sur	0,218	382
		-----	0,171	
		Este-Oeste	0,123	

Cuadro 2. Valores promedio de los frutos producidos en cladodios con diferente orientación, en ambos lados de la planta. (Becerra, Barrientos y Díaz, 1975).

Orientación de cladodios	Lado de la planta	Cladodios con Frutos/Planta	Frutos/Planta	Frutos/Cladodios
Norte-Sur	Este	8.4	31.5	2.9
Norte-Sur	Oeste	7.6	28.5	3.1
		N.S.	N.S.	N.S.
Este-Oeste	Este	5.4	16.1	2.7
Este-Oeste	Oeste	5.5	19.2	3.1
	Este	6.9	23.8	2.8
		N.S.	N.S.	*
	Oeste	6.5	23.7	3.1
Norte-Sur		8.0	29.9	3.1
		**	**	**
Este-Oeste		5.4	17.6	2.9

N.S. No significativa estadísticamente.
 * Significancia al 0.05 de probabilidad.
 ** Significancia al 0.01 de probabilidad.

Cuadro 3. Composición química (inicial) del jugo de tunas cosechadas a diferentes grados de madurez.
(Alvarado, Barrientos y Lakshminarayana, 1978).

Composición química del jugo	Días transcurridos después del amarre del fruto					
	91	98	105	110	115	120
Sólidos solubles totales (°Brix)	9.70	13.40	14.55	14.80	15.80	15.50
Acidez Titulable (% Ac. cítrico anhidro)	0.15	0.11	0.12	0.08	0.05	0.03
Acido Ascórbico Verdadero (mg/100 ml)	16.34	13.90	21.40	14.10	11.60	22.05
pH	5.70	6.00	6.20	6.25	6.10	6.60
Glucosa (%)	4.36	7.80	4.67	8.40	11.98	8.19
Fructosa (%)	5.74	6.92	10.06	8.05	5.84	6.71
Sacarosa (%)	1.50	1.03	0.80	0.00	0.00	1.10
Azúcares totales (%)	10.85	15.01	15.22	15.85	17.54	16.04

La gravedad específica del fruto aumentó rápidamente desde la 14a, semana en que fue mayor que 1.0.

Como índices de cosecha se recomienda utilizar la gravedad específica y el contenido de sólidos solubles y físicamente la profundidad del receptáculo (cuadro 3).

En general, podemos decir que los conocimientos anteriores en las especies del género *Opuntia* han servido de base a los trabajos de mejoramiento genético, prácticas culturales, producción y manejo de la producción de ese frutal.

Variedades Productoras de Fruto

En el programa de mejoramiento de nopal en el Colegio de Postgraduados se ha trabajado principalmente con variedades seleccionadas de la especie *Opuntia amyclaea* (Tuna blanca o de Alfajayucan). Las F₁ resultantes de la cruce de la colección Mex 23 de San Martín de las Pirámides con la Hgo. 64 de Ajacuba, Hgo., fueron establecidas en lotes de selección en diferentes estados: en semillero por vigor; en vivero, mediante una competencia completa, por vigor, resistencia a frío y a enfermedades y plagas; en planta adulta por adaptación, producción, calidad de fruta y tolerancia a plagas y enfermedades.

Se establecieron lotes en diferentes partes de la República para la estimación de adaptación. En particular en Zacatecas, Aguascalientes, Puebla, Hidalgo, Oaxaca, Yucatán, Guanajuato, Nuevo León, Veracruz, Guerrero, Michoacán, Baja California, Morelos, Durango y en el Edo. de México. Se han obtenido clones de grandes posibilidades tanto por su producción como en la calidad de sus frutos y su producción escalonada.

Los niveles de producción en los lotes experimentales avanzados hasta 1976 produjeron alrededor de 22 toneladas por hectárea para las variedades COPENA T-1 y T-2, en Tecamachalco, Pue. (García Santibáñez, 1976). En la misma localidad, Cruz Hernandez (1981) reportó rendimientos hasta de 30 toneladas por hectárea de fruto, con la variedad COPENA T-3, y rendimientos totales de cuatro años de 85.4 toneladas por hectárea, para la variedad COPENA T-5 (cuadro 4).

El fruto presenta características según las variedades, por ejemplo: el peso promedio de frutos para 1976 fue de 101 gramos para la variedad 17 y de 221 para la 19; para las mismas variedades el peso de la cáscara fue de 30 y 99 gramos respectivamente; el peso del lóculo de 80 y 122 gramos; el número de semillas abortivas 59 y 172; y en sólidos solubles 15 y 14% respectivamente. La madurez promedio en la primera variedad es el 10 de septiembre, mientras que en la COPENA 19 es el 10 de agosto (cuadro 5).

Cuadro 4. Producción de variedades de nopal "Copena" bajo condiciones de temporal del Valle de Valsequillo, Pue. (Cruz, H. P. 1981).

Selección	1974	Producción en ton/ha/año				Total	- X
		1975	1976	1977	1978		
Copena T no. 2	3.5	19.8	12.2	21.5	15.3	72.3	14.4
Copena T no. 3	1.4	20.2	12.3	30.0	17.5	81.4	16.2
Copena T no. 5	1.9	13.8	20.5	25.7	23.5	85.4	17.8

Variedades Mejoradas Forrajeras

La variedad mejorada recomendada para forraje se ha designado COPENA F-1*. En las observaciones preliminares, esta planta llamó la atención en los lotes de selección, debido a su rápido crecimiento y ramificación, posteriormente, dentro de otras selecciones se observó que la preferían los roedores y hormigas, lo cual era un indicio de su palatabilidad. Las variedades potenciales se incrementaron rápidamente por el método de fracciones mínimas, desarrollado por Barrientos y Brauer (1964), utilizando partes de la penca con una sola areola para obtener plantas rápidamente.

Las variedades potenciales pertenecían a las especies Opuntia ficus indica y Opuntia robusta. Valdés G. y Flores V. (1967b) probaron la aceptación del ganado ovino a las variedades mencionadas, encontrando una mayor aceptación para COPENA F-1 cuando tenían libre acceso a todas. También se estudiaron niveles de consumo de las mismas especies, obteniéndose mayores consumos (11.0 kg diarios por animal) de O. ficus indica que de O. robusta (6.5 kg). Los borregos alimentados con las variedades de O. robusta sufrieron diarrea.

* Colegio de Postgraduados, forrajera 1.

Cuadro 5. Características de variedades de nopal productoras de fruto en Chapingo, México.

No. de Selección	Fecha de maduración	Peso promedio fruto gr.	Peso de cáscara gr.	Peso de lóculo gr.	Semillas normales	Semillas abortivas	Grados Brix
Copena 1	30/8/76	138.3	47.9	90.7	201.9	59.2	16.0
Copena 12	2/9/76	182.8	42.1	90.0	202.9	68.6	15.8
Copena 13	20/8/76	123.0	42.0	79.9	187.3	49.7	16.4
Copena 14	20/8/76	127.2	46.8	76.7	204.7	59.4	16.2
Copena 15	16/8/76	186.6	52.6	83.8	220.9	66.4	15.4
Copena 16	8/9/76	112.0	38.8	72.5	166.8	54.0	15.6
Copena 17	10/9/76	101.0	29.5	79.9	198.9	58.8	15.5
Copena 19	14/8/76	221.3	98.7	122.3	249.9	172.5	14.7

Barrientos (1965) encontró que: (a) los rendimientos de forraje verde son similares cuando se depositan las pencas sobre la superficie del suelo, que cuando se entierran parcialmente, para establecer las plantaciones. Puesto que el primer método es más económico se considera ventajoso su empleo, (b) el nopal responde notablemente al estercolado, (c) con densidades de 40,000 plantas por hectárea, en hileras separadas un metro, con una mínima separación entre plantas (0.25 m) y dos cortes por año, pueden obtenerse alrededor de 400 toneladas por hectárea por año, a partir del tercer semestre de establecida la plantación.

Las dificultades en la estimación de los rendimientos son grandes, en particular, debido a que el mayor contenido del nopal es agua, por lo tanto el tonelaje por hectárea es una medida muy burda de estimación; sin embargo, es un índice del potencial de la planta, inclusive precisamente por su capacidad de almacenamiento de agua.

García (1973), inició un experimento en 1970, para estudiar la producción de forraje verde de nopal, obtenida con diferentes niveles de fertilización y riego. Los niveles de 200 kg de N por hectárea y 100 toneladas de estiércol por hectárea dan el rendimiento máximo por hectárea (186 ton), sin riego; a los mismos niveles y con riego se obtuvieron sólo (175 ton), el testigo produjo en promedio (82 ton). En general se concluye que hay respuesta a la aplicación de estiércol y al nitrógeno y fósforo combinados. En apariencia no existe ventaja en la aplicación del riego bajo las condiciones del experimento. Se nota en este caso, lo mencionado acerca de la variación en las estimaciones de rendimiento, sin embargo es importante observar las tendencias. Se podría comentar que en el caso de García se hicieron cortes periódicos y se estimó el rendimiento mientras que Barrientos (1969), efectuó los cortes considerando la edad fisiológica de la planta y no fechas predeterminadas. Flores (1977) considera que comparando el nopal (COPENA F-1) con otros forrajes que se utilizan actualmente en la alimentación invernal de bovinos de leche en el área de Chapingo tiene buenas posibilidades.

Barrientos (1972), estudió diferentes densidades de nopal en terrenos tepetatosos de temporal en el área de Chapingo, con el objetivo principal de estudiar las tendencias en producción. La plantación se estableció con pencas de un semestre de edad en 1967 y se cosechó en 1969. Las densidades variaron de 5,000 a 80,000 plantas por hectárea, y los resultados obtenidos son los siguientes: para la densidad mínima se produjeron 43,500 pencas y con la máxima 245,250 pencas, equivalentes a (27 ton) y (65 ton) por hectárea, respectivamente. Las observaciones derivadas se podrían resumir como sigue: (a) hay un aumento en el número de pencas cosechadas a medida que aumenta la densidad, (b) el peso promedio de las pencas disminuye a medida que aumenta la densidad, (c) exista un aumento en producción en toneladas por hectárea a medida que aumenta la densidad.

Los resultados obtenidos en los experimentos anteriores nos dan indicaciones muy claras en cuanto al manejo de las plantaciones de nopal para forraje, es decir, es conveniente establecer plantaciones con alta densidad (80,000 ha), lo cual se consigue con surcos de 0.5 m, con plantas a 0.25 m; esto puede realizarse en forma de setos dejando únicamente espacio para el tránsito de vehículos durante el corte; por otra parte, el esquema propuesto da indicaciones para su empleo como seto vivo para detener la erosión, en los terrenos erosionados, pudiendo intercalar otros cultivos en forma de terrazas. La aplicación de estiércol se considera conveniente máxime que se piensa utilizar al nopal para eliminar ganado que a su vez producirá estiércol. El corte deberá efectuarse en forma semestral de acuerdo a las condiciones de crecimiento regionales.

Valdés (1977), determinó la composición química y la digestibilidad aparente de la variedad COPENA F-1 utilizando la recolección de haces en estado de mantenimiento. Considera el autor que es un forraje pobre en nutrientes, son una digestibilidad regular. De la revisión bibliográfica realizada se concluye: (a) que el nopal es un forraje con un gran contenido de agua y pobre en materia seca, (b) es un forraje tosco en base al nivel de energía que se metaboliza por kg de materia seca, (c) por su energía digestible, se debe considerar al nivel de los forrajes toscos de la época de escasez, como las pajas, rastros y silos.

En fecha muy reciente, en la Sociedad Americana de Ciencia Animal, Lastra et al. (1977) presentaron un trabajo que causó gran interés: "Evaluation of thornless prickly pear silages as a feedstuff for ruminants". En dicho trabajo realizado con la variedad COPENA F-1, se hicieron silos con aditivos de gallinaza, urea y urea con melaza. Al comparar con respecto al testigo sin aditivos encuentran que en todos los casos ocurrió una buena fermentación, dando un silo de buen color y olor excepto con la gallinaza. En cuanto a la aceptación fue buena, correspondiendo la mayor con grano de sorgo, urea y melaza y por último con la gallinaza. Todos los aditivos aumentaron en forma significativa la materia seca y proteína de los ensilajes. La digestibilidad (In vitro) de la materia seca y orgánica aumentó con sorgo y urea con melaza. La digestibilidad (in vivo) muestra la misma tendencia excepto, que la urea con melaza fue la más alta. El mayor consumo del ensilaje fue el de nopal y harina de girasol.

Variedades Productoras de Verdura

Se ha seleccionado la variedad COPENA V-1 para verdura, principalmente por su buena capacidad para la producción de brotes succulentos y sin problemas de acidez.

Grajeda (1977) ha logrado con esta variedad producciones elevadas de verdura durante las épocas de más demanda en el mercado como lo es en el invierno, mediante frozamiento en túneles de plástico. La producción promedio en estos túneles ha sido hasta de 40 kg por m², en cortes cada 15 días al tamaño comercial requerido. La plantación más eficiente es en forma su perintensiva con pencas de un comestible de edad a distancias de 10 cm por 25 cm.

En esta variedad se presentó un ataque severo de la enfermedad conocida por "Engrosamiento de Cladodios" (Pimienta, 1974). Por este motivo fue la primera variedad en donde se ha producido material fundador por medio del cultivo de tejidos (Barrientos, 1976).

PLAGAS Y ENFERMEDADES

El nopal empleado para verdura presenta pocos daños de plagas; sin embargo, recientemente se ha incrementado una enfermedad, posiblemente virosa, caracterizada por el engrosamiento de cladodios y suspensión del crecimiento. Mediante tratamientos de calor y cultivo de meristemos *in vitro* fue posible obtener plantas sanas, lo cual ha permitido obtener material 'fundación' y las metodologías de propagación que serán la base de programas de certificación (Barrientos, 1964, 1978).

En los últimos años ha proliferado una enfermedad bacteriana que causa pudriciones, que destruyen a las plantas con suma rapidez, sobre todo en ambientes fríos y con alta humedad relativa, se ha caracterizado el género *Erwinia* como el organismo causal, pero la especie no está determinada.

Otra enfermedad conocida comúnmente como el 'Oro', está relacionada con cambios bruscos de temperatura, que producen daños que facilitan la entrada de microorganismos.

Los nopales productores de fruto presentan daños considerables por las plagas siguientes: *Cactophagus spinolae* Gyll., *Cylindrocopturus biradiatus* Champ., *Hesperolabops gelastops* Kirk., *Sericothrips opuntiae* Hood., *Laniifera cyclades* Druce., *Olycella nephelepasa* Dyar., *Dactylopius indicus* Green., *Chelinidea tabulata* Burm.

García Mayoral (1965) considera que el combate de las plagas del nopal puede hacerse mediante las medidas generales siguientes:

- (1) Destrucción de toda clase de malezas que crezcan en el terreno cultivado con nopal a fin de mantenerlo limpio.
- (2) Revisión constante de las nopaleras nuevas libres de plagas y destrucción inmediata por medios mecánicos de cualquier brote de aquellas especies de mayor tamaño (grandes), como *Cactophagus*, *Laniifera* y *Olycella*, mediante la captura y extirpación y extirpación de larvas y adultos.

- (3) Si el cultivo ya está infestado, los procedimientos generales de combate son los siguientes: captura y extirpación de las especies grandes en la época de mayor incidencia. Las otras especies pueden ser atacadas eficazmente con insecticidas en polvo.

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Summary.--The brick pear (*Opuntia* spp.) is an abundant plant in Mexico and presents a great polymorphism, many different wild and cultivated species exist. For the inhabitants of the desert and semidesert areas, this plant is very important, as its fruits or tender buds can be used directly for human food and for cattle food as well, mainly when other forages are scarce due to the lack of moisture in the soil. It is also used in industry for the manufacture of food, and in other products, too.

Because of the genetic variability of the material, the natural and artificial selective pressure, as well as of the sexual and asexual reproduction, there are different types, which grow in different environmental conditions. Some of them are highly distributed and are very abundant, such as *Opuntia streptacantha* and *Opuntia leucotricha*, known as "nopal cardón" and "Duraznillo", respectively. Such species are mainly found in the Potosina-Zacatecana Central Area, mentioned by Valazquez (1962), delimiting 38,000 km² for "nopal cardón" of which approximately 50% is exploited; and, 45,000 km² for the "duraznillo" of which 15% is exploited (Borja, 1963).

Some areas as the one in Teotihuacan and others in the state of Hidalgo are known by the quality of the fruits of their brick-pears, particularly the white fruit of the *Opuntia Amyclaea*. In Milpa Alta, D. F., the brick-pear is raised as a vegetable, and it is mainly sowed for this purpose.

25 The Prickly Pears (*Opuntia* spp.): Plants with Economic Potential¹

Charles E. Russell and Peter Felker²

Abstract.--The cactus family contains many economically promising species primarily in the genus *Opuntia*. This genus appears to have its center of genetic diversity in Mexico where it is widely used for fodder, forage, fruit and green vegetables. Since the Crassulacean Acid Metabolism of the Cactaceae can result in a four- to five-fold greater efficiency over most grasses in converting water to dry matter, cacti are ideally suited for water-short areas. In the southwestern United States, prickly pears (e.g. *Opuntia lindheimeri*) have been considered both weeds and valuable forage plants. This presentation discusses *Opuntia* spp. as crops such as fodder, forage, fruit and green vegetables. We specifically discuss their potential as a range forage to ensure an inexpensive stock feed during the frequent, unpredictable droughts in South Texas and northeastern Mexico. During these droughts, propane torches, known as "pear burners", are used to singe the spines off cactus pads so that they can be eaten by livestock. Although thornless varieties of *Opuntia* can be consumed directly by domestic livestock, they are subject to herbivory by wildlife as well. As an emergency stock feed, cacti are more dependable than grass and may offer a means of extending greater sustained carrying capacity to certain drought-prone range-lands.

INTRODUCTION

In North America prickly pear is the common name for any flat-stemmed cactus of the genus *Opuntia*. Historically and prehistorically, these cacti have played an important role in the life of the inhabitants of present-day Mexico. The founding of Mexico City in 1325 on an island in Lake Texcoco was based on an omen containing reference to "nopal" or cactus. In his book on the discovery and conquest of Mexico, Bernal Diaz describes the fruits and pads of cacti as common food when he and Hernando Cortes entered Tlascala in September, 1519. References to cacti abound in the mythology and art work of ancient and present-day Mexico where a cactus is part of the emblem of that nation.

Most of northern Mexico is considered arid or semiarid. In this area cacti make up a large part of the vegetation and are used extensively for human food, as well as animal fodder and forage. (The word fodder is used in this paper for plant material grown and harvested for livestock, whereas, forage is material range animals seek and consume in the field.) Thus, it is appropriate that this work on cacti began in Mexico where scientists such as Roberto Nava C. at the Universidad Autonoma Agraria Antonio Narro, Efraim Hernandez X. and Ernesto Riquelme V. at the Colegio Postgraduados, Chapingo, were able to suggest sites to visit as well as provide information and data on the ecology and use of cacti.

Despite the widespread use of cacti in Mexico and other parts of the world, there has been little applied research on their use in the United States since the pioneering work of Griffith from 1905 to 1915. Unfortunately, while there is little doubt cacti are important food, fodder and forage crops worldwide, the scientific literature on their economic potential is too old and fragmentary to begin research without field-trial validation and a thorough review of the Mexican, North African, South African and South American literature which is not easily obtained in the United States. Consequently, we have begun a two-year project to collect literature and germplasm for

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the field evaluation of selected cactus varieties.

GENETIC RESOURCES AND NATURAL DISTRIBUTION

The Cactaceae family contains approximately 130 genera with about 1,500 species which are originally native only to the New World (Monjauze and Le Houerou 1965). Although cacti are primarily associated with dry subtropical areas, Opuntia polycantha Haworth occurs at 53°N latitude in Alberta, Canada, and O. australis Weber occurs at 50°S latitude in southern Argentina. O. rafinesquei Engelm. has become naturalized in the mountains of Valais, Switzerland, and undoubtedly possesses the greatest cold tolerance (Monjauze and Le Houerou 1965).

Feldger (1979) described three major growth forms of economically important cactus: the large columnar cacti, the shrub-sized prickly pear and chollas, and the small pin-cushion cacti. He also cites work indicating a high degree of hybridization within the family. The Opuntia species studied to date appear to be a polyploid series containing diploid ($2n = 22$), tetraploid and octaploid forms which are propagated vegetatively (Hernandez X. 1970).

Opuntia ficus-indica L. was introduced to Spain from the New World by Christopher Columbus. Within a short time, it had become naturalized throughout Spain and in 1610 was carried to North Africa with the last departing Moors. Due to Spain's influence, Opuntia ficus-indica had spread throughout Italy, Greece and the Mediterranean by the end of the 18th century. In 1965, it occupied 100,000 ha in Sicily, 6,000 ha on Sardinia and 60,000 to 80,000 ha in Tunisia (Monjauze and Le Houerou 1965).

All cactus plants have Crassulacean Acid Metabolism (CAM) and can thus have a four- to five-fold greater efficiency than most grasses in converting water to dry matter (Kluge and Ting 1978). Because they are so water use efficient, cacti are ideally suited for many arid and semi-arid ecosystems.

CACTUS AS A FRUIT CROP

Griffith and Hare (1907) reported that in 1905 Italian varieties of cactus fruit or prickly pear (known as "tunas" in Spanish) were available in Washington, D.C. markets for several months. At that time, cactus fruits in commercial use typically were pear- or fig-shaped and 2-7 cm in diameter. The amount of pulp in the various varieties they studied was from 30-60 percent with the best-tasting varieties containing the largest percentage of pulp. Griffiths and Hare (1907) also described various cottage industries and products prepared from the cactus fruit and fruit juice. Among those products were "tunas secas" or dried fruit, "colonche" a fermented drink, a fermented drink, "miel de tuna" (tuna honey), which was a molasses or honey-like product, and "queso de tuna" (tuna cheese), a

product similar to pulled taffy.

More recently, we have observed and purchased fruits in California, Chile, Mexico and Texas. Analysis of a commercial Chilean cultivar, grown in our greenhouse, by the USDA Agricultural Products Quality Research Laboratory in Weslaco, Texas, revealed that the fruit had a pH of 5.8 and a fresh-weight sugar content of 0.2% sucrose, 7.0% glucose and 4.8% fructose. In addition, a taste panel of 10 individuals rated the fruit at 7.6 on a scale with a maximum value of 9.

Hernandez X. (1970) reported that in Mexico eight metric tons of top quality fruit can be expected within four years of plantation establishment at a plant density of 2,000 per hectare. Full production is reached in about the twelfth year and continues for at least 20 years thereafter. A two- and one-half-year-old plantation in San Luis Potosi, Mexico was visited in May of 1984 by Russell (unpubl. data) which had a plant density greater than 2,000 per hectare and was bearing its first crop. The selected varieties in this plantation were coming into production a full year sooner than those cited by Hernandez X. (1970).

Since Dr. Barrientos will undoubtedly discuss tuna production in Mexico, we wish to mention a South American country which has an economically important tuna industry. In Chile there are active research programs at both the Pontificia Universidad Catolica, led by Antonio Lizana M., and the Universidad de Chile, under David Contreras T. and Fusa Sudzuki H. on tuna production, marketing, postharvest physiology and utilization. In Chile tunas are grown in well-organized plantations either in monoculture or, at times, intercropped with tree fruit such as almonds, apricots and olives (Russell, unpublished data, 1984).

It is reported that the better plantations produce 9 to 15 tons of fruit per hectare (Toroni C. and Zuniga O. 1983). In the tuna producing areas of Til-Til, Pudahuel and Noviciado where irrigation is available, fertilized plantations produce two crops per year. There is a summer crop from February through April and a smaller, but economically important, winter crop in October. In response to questions about growing tuna where tree fruit or grapes could be grown, the growers indicated that with less infrastructural costs tuna production is as profitable on their marginal lands as tree fruit or grapes. This is particularly true on sloping land or where they do not have irrigation.

It thus appears that there is ample diversity within commercially accepted varieties for adapting prickly pear fruit production to differing climatological, management, and soil conditions. The pulp-to-seed ratio and shelf life compare favorably with traditional fruits and berries on the commercial market in the U.S. Thus, consumer acceptance should not be a problem if the fruit was available in the U.S. Given current

agricultural land values in semiarid areas, it is probable that cactus fruit production could substantially increase returns to landowners.

CACTUS AS A VEGETABLE CROP

"Nopalitos" are the tender, young pads of the cactus plants eaten as a vegetable in Mexico and the southwestern United States where there are large populations of people with a Mexican heritage. In the Lenten season, these pads are prepared as a cooked green vegetable or a marinated vegetable particularly during "Holy Week." In Mexico, the production of nopalitos as a vegetable crop is centered in the areas of Milpa Alta, Distrito Federal, the state of Mexico, and the state of Puebla. Milpa Alta was visited at the suggestion of E. Hernandez X. in May 1984 and crop production was discussed with several growers (Russell, unpubl. data). Milpa Alta, which means "high corn field," is a small valley at about 2400 to 2600 m elevation in the shadow of Popocateptl about 25 km south of Mexico City.

At the time of the visit the entire cropping area of the valley was in nopalito production with a cactus known as nopal de Casaila (*Opuntia ficus-indica*). Plantations for vegetable production have about 40,000 plants per hectare planted about 30 cm apart within rows and 80 cm between rows. The first crop can be harvested in two or three months and well established plantations yield 80-90 metric tons per hectare (Anon. 1981). Material which is not sold on the vegetable market is used for dairy cattle fodder. The local dairy operations supply the fresh manure which is liberally applied to the fields every third year for moisture conservation and the only source of fertilizer.

At the time of the visit, Milpa Alta appeared to be a remarkably prosperous area. The reason given by local growers for changing from corn to cactus was that corn was frequently a marginal crop dependent on the highly variable rainfall, and they could consistently make more money growing cactus. Thus, the steep, semiarid land at Milpa Alta might serve as an example of converting marginal land into productive land by simply growing an ecologically appropriate crop.

CACTUS AS FODDER AND FORAGE

South Texas and northeastern Mexico are semiarid to subhumid climatic environments. The growing season exceeds 300 days, and the average rainfall ranges between 380 mm and 720 mm with a bimodal precipitation regime. Although a median rainfall can be calculated, the area is characterized by pronounced variability with no predictable rainfall (Norwine, 1981). Local ranchers maintain that three or four out of seven years will be drought years from the standpoint of obtaining a grass crop on rangelands. This unpredictability creates problems for range management which frequently result in rangelands

being severely degraded by overgrazing. This is further exacerbated by cattlemen generally equating rangeland with grassland regardless of its ecological validity in the local environment.

Frequently large sums of money are spent converting coastal plain and chaparral into grassland which can be maintained for limited periods. Animal unit allotments based on the estimated forage production of the introduced grasses generally use the median rainfall estimate which, as shown in Figure 1, is not predictable for the anticipated growing period.

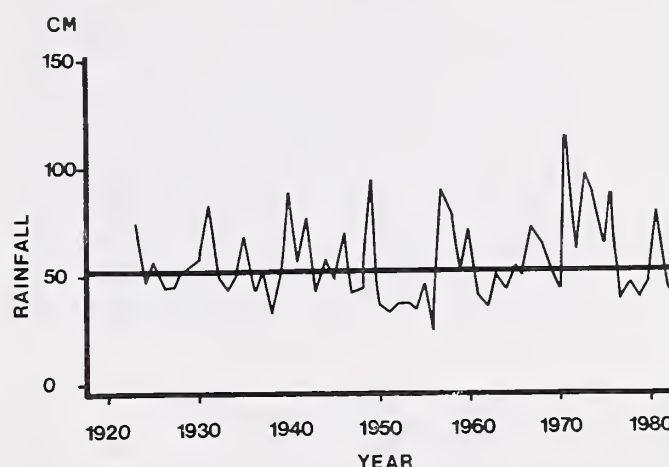


Figure 1. Total annual precipitation, Cotulla, Texas (1923-1983). Data from NOAA, National Climatic Center, Asheville, N.C.

In light of the known variability of the precipitation regime, we believe that prickly pear should be included in any range management scheme in this and similar areas throughout the world. The vegetative part of the cactus can be spiny or spineless and has been widely used for livestock fodder and forage in semiarid regins. While cactus is low in protein, its digestible energy production per unit of water is high. Thus, cactus should provide a good complement to semiarid-adapted nitrogen fixing, high protein plants like *Leucaena* (Brewbaker and Hutton 1979), *Prosopis* (Felker and Clark 1982) and the grasses preferred for livestock forage.

Cactus has been described as an unbalanced ration that is low in protein and lipids, but rich in digestible carbohydrates, water and vitamins (Monjauze and Le Houerou 1965). It is perhaps fortunate that cactus is low in protein, otherwise, its leverage of water to dry matter production would be nitrogen limited. The fresh and estimated dry weights of cactus pad production are presented in Table 1. Dry weight yields were generally not reported, but were calculated as 13 percent of wet weight from a review of 13 cactus productivity reports by Monjauze and Le Houerou (1965). The highest yield is from a well-established and tended experimental plot at Chapingo, Mexico (Riquelme V., pers. comm., 1984). The dry weight yields are high for semiarid ecosystems and indicate that with variety selection and

some basic research, target values of 30 to 40 mt/ha/yr are reasonable.

In South Texas, prickly pear (e.g. O. lindheimeri Englem.) is widely known as an emergency drought feed for cattle. In drought periods when grasses have been overgrazed or become senescent, cactus remains succulent and green, with a normal complement of vitamins and carotenoids (precursors to vitamin A). Numerous modifications of propane torches known as "pear burners" have been used to singe cactus spines so that cattle can eat the pads. During the drought of the 1950s in Texas, pear was held in high esteem by cattlemen.

We suggest that prickly pear can be grown as a fodder crop on land which is presently deemed marginal for other crops (e.g. corn and sorghum) because of its greater water-use efficiency. This fodder can be of either the spiny or spineless varieties (Griffith 1908). In addition to burning the spines off with pear burners, harvested spiny pads can be tumbled and chopped to remove the spines for confined cattle in a feed lot or dairy operation (Griffith 1905, 1906).

In the northeast of Brazil, Opuntia ficus-indica has been grown as a fodder crop for about 80 years. Presently, there are approximately 300,000 hectares in cactus

plantations, about 95 percent of which are located in the states of Paraiba, Pernambuco and Alagoas. At the EMBRAPA/CPATSA experiment station near Petrolina, Pernambuco, Severino Gonzaga de Albuquerque has been conducting field trials for three years on various intercropping regimens of cactus, with mesquite or algaroba (Prosopis spp.), grain sorghum (S. bicolor) and cowpeas (Vigna unguiculata) (Russell, unpublished data, 1984). This area is notoriously dry, has a brackish water table just a few meters below the surface, and receives all of its annual precipitation during one short rainy season. Thus, ranchers are faced with an approximately 40 week drought every year. Local ranchers claim cactus is the only thing they have to carry livestock through the annual dry season. It provides not only the carbohydrates, but also biological water (i.e. the water stored in the cactus pads) in an area where there is no surface water 80 percent of the time in a normal year. These ranchers are in essence farming water!

Finally, prickly pear can be used to provide greater sustained carrying capacity to drought-prone rangelands. By incorporating it into a more diverse range ecosystem, it can assure abundant emergency stock feed during drought seasons. Presently in South Texas, it costs about 35 cents per animal unit per day to maintain cattle on prickly pear, whereas "relief"

Table 1. Summary of cactus dry matter production.

Location	Rainfall (mm/yr)	Cultivation	Freshweight mt/ha/yr	Dryweight ¹ mt/ha/yr	Source
Mexico	-	-	400	52	Riquelme V., 1984
Mexico	-	-	200	26	Hernandez X., 1970
Italy	-	-	60	7.8	Monjauze & Le Houerou, 1965
Sicily	-	-	60-65	7.8-8.5	Monjauze & Le Houerou, 1965
Morocco, S. Africa, Algeria	-	-	100-300	13-39	Monjauze & Le Houerou, 1965
Brazil	300	-	140	18	Monjauze & Le Houerou, 1965
Tunisia	150-400	No	25-102	3.2-13	Monjauze & Le Houerou, 1965
Brownsville, TX	-	-	44-123	5.7-16	Griffith, 1915
San Antonio, TX	700	Yes	51	6.6	Griffith, 1908
San Antonio, TX	700	No	6.3	0.81	Griffith, 1908

¹The 13% dry matter content used here was typical of 13 dry matter values reported in the review of Monjauze and Le Houerou (1965).

corn supplied by the federal government from its reserves costs 78 cents per day, and alfalfa is about 109 cents per animal unit per day (Maltsberger, per. comm.). If cattle must be carried for an extended period on cactus, they need an additional 24 cents-worth of cottonseed meal per day. Since it is not uncommon to carry cattle 100 or more days before unpredictable rains allow other forages to come back, the economics (e.g., 50 cents per animal unit per day) are clearly in favor of prickly pear over alfalfa or infrequently supplied "relief" corn from the government.

As an example, one cattle producer in South Texas has had his cattle on prickly pear and either cottonseed or cottonseed meal for more than a year now. During this period of time, the area has suffered one of its frequent droughts. While his neighbors have had to sell off their cattle or let them die, he has increased his herd eight percent. He also states that the conception rate of his Santa Gertrudis cattle is four to five percent better for a 60-day breeding period than if they were on normal dry grass range. In December, 1984 he sold dry cows at about 42 cents per pound (live weight) weighing an average of 1200 pounds (545 kg) each. In February, 1985 he again sold dry cows, but at 52 cents per pound, weighing an average of 1285 pounds (583 kg) each.

This rancher now believes that cactus should be a permanent part of his cattle operation. He is no longer going to wait for a drought to utilize prickly pear, but will continue to feed his cattle cactus every year whether it rains or not. He is thus planting prickly pear in rows to increase the fuel use efficiency to burn the spines off. He is going to try to use cactus for 30 percent of the total annual diet in normal years (400-500 mm) and 50 to 60 percent in dry years. By using cactus to supplement the diet of his cattle, he will increase both the carrying capacity of his land and the quality of the range for forages other than cactus.

The ability to carry livestock over a drought on prickly pear has tremendous implications for drought-prone areas. If producers can avoid selling when a drought begins and then trying to catch up with their forage by buying back livestock when the drought ends, they can avoid the common "buy high and sell low" cycle so prevalent in semiarid regions. The more stable livestock population numbers remain, regardless of the drought cycle, the more profitable the ranching operation should be.

In addition to feed for livestock, prickly pear provides food and cover for wild animals. In some areas of the western United States and northern Mexico, hunting revenues equal or exceed the income from livestock production, suggesting that ranchers should consider the other benefits of prickly pear on their rangelands (Ramsey 1965; Teer 1975; Arnold & Drawe 1979; Everitt & Gonzalez 1981).

CONCLUSION

We have discussed the potential of cacti, fruit and vegetable crops. Its water-use efficiency and long history of use in Mexico suggest it would be valuable in other semiarid ecosystems, both in the United States and elsewhere. We especially want to draw attention to the possibility of using prickly pear as forage crop in drought-prone areas. The vegetative part of the cactus can be spiny or spineless and has been widely used for livestock fodder and forage in semiarid regions. The spiny varieties should be planted or encouraged, not eradicated. During favorable forage production years, these plants, protected from animal predation by their spines, would sequester water and mineral nutrients while producing carbohydrates and vitamins which could be made available during drought seasons more economically than alternative feeds. Although thornless varieties of *Opuntia* spp. can be consumed directly by domestic livestock, they are subject to considerable herbivory by wildlife as well.

ACKNOWLEDGMENTS

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Resumen.--La familia de cactus contiene muchas especies de importancia económica, particularmente en el género *Opuntia*. Este género parece que tiene su centro de diversidad genética en México donde se usa como pastura, forraje, fruta y verduras verdes. Porque el metabolismo ácido crassulacean de Cactaceae puede resultar en cuatro a cinco veces más eficiencia sobre más de otras gramíneas en convertir agua a materia seca, cacti son idealmente adecuados para áreas áridas. En el suroeste Estados Unidos, nopales (e.g., *Opuntia lindheimeri*) se han considerado como malezas y plantas forrajeadas de importancia. Aquí se discute *Opuntia* spp. como cosechas de pastura, forraje, frutas y verduras verdes. Discutimos específicamente su potencial como forraje de campo para asegurar un alimento barato de ganadería durante las frecuentes e inciertas sequías en Texas sur y nordeste México. Durante estas sequías, antorchas de propano, conocidas como "quemadoras de nopal", se usan para chamuscar las púas para que se puedan comer por ganadería. Aunque variedades de *Opuntia* sin púas se consumen directamente por la ganadería, también son consumidas por la fauna silvestre. Como alimento de emergencia para ganadería, cacti son más confiables que gramíneas y pueden ofrecer un modo de extender más la capacidad de mantener a ciertos pastizales que sufren sequías.

245 Impacto de la Ganaderia en la Utilizacion de Especies Nativas y su Clasificacion en el Estado de Sonora¹

Ing. Rafael Aguirre Murrieta²

Resumen.--El uso y manejo de las plantas forrajeras de las zonas áridas de Sonora es inadecuado y la utilización excesiva y destructiva, además de que algunas plantas aunque forrajeras, quizás tienen para el futuro otros valores y usos, inclusive en la alimentación humana e industrial; falta investigación y experimentación, educación y entrenamiento y técnicas especializadas en el manejo, conservación y mejoramiento de éstos recursos bióticos.

Una de las utilizaciones más grandes, en forma masiva, que se hace de las plantas de las zonas áridas, es realizado por el ganado doméstico y fauna silvestre de las llamadas plantas forrajeras y que en el Estado de Sonora son parte medular de la actividad y economía ganadera.

La ganadería es una actividad económica sumamente importante, que representa después de la agricultura, la ocupación más generadora de empleos divisas y alimento básico. Pero en el desarrollo tecnológico aplicado se considera un atraso entre 50 y 60 años, en relación a la agricultura. Este atraso ha traído como consecuencia un mal manejo de los recursos del pastizal y es en gran parte culpable actual de la situación del deterioro de estos recursos tales como:

Destrucción acelerada de la vegetación
invasión de plantas no forrajeras y tóxicas
al ganado

Alza en los costos de producción

Baja producción animal

Erosión acelerada

Asolve en las presas, que acortan su vida útil

-Esguimientos de alta velocidad que provocan daños, inundaciones y erosión. -Pérdida en la capacidad de captación de agua en las cuencas hidrologicas. -Baja en cantidad y calidad de agua para las Zonas agrícolas y Centros urbanos en las Zonas bajas.

Existen evidencias en cambios de vegetación en algunas Zonas en los últimos 80 años que coinciden con el desarrollo de la ganadería en el Estado, siendo en éste, donde se encuentra mayor información al respecto, existieron a fines del siglo pasado y principios del presente alrededor de 10 millones de has. de pastizales abiertos y asociados con arbustos y árboles en la actualidad existen 2.3 millones de has. de los cuales en 1966 al iniciar COTECOCA los estudios de vegetación 250 000 has. eran de pastizal mediano abierto, con dominancia de especies del género *Bouteloua* y actualmente este pastizal se encuentra deteriorado con procesos graves de erosión e invasión de gramíneas anuales y especies arbustivas no forrajeras, pudiéndose decir, que ya es un pastizal con arbustos como el resto del pastizal encontrado y este último ya presenta invasiones de especies de matorrales.

Sonora tiene 18.5 millones de ha., de las cuales el 75% se consideran de agostadero; se han identificado y delimitado 25 tipos de vegetación entre bosques, pastizales, matorrales, selva baja, etc. además de la vegetación costera de dunas, halófitas y manglar; dominando en superficie los matorrales y pastizales de zonas áridas y que ocupan el 89% de la superficie de agostadero.

Dentro de estos tipos de vegetación se han identificado alrededor de 58 sitios de productividad forrajera, clasificándolos dentro de cada tipo de vegetación del más al menos productivo según sus especies forrajeras claves.

Dentro de esta clasificación se han elaborado listas de plantas forrajeras enlistándolas como deseables y menos deseables desde el punto de vista de manejo de pastizales y tipos de menos deseables o invasoras que no por no ser forrajeras dejan de tener importancia ecológica y económica para otros usos, como el caso de la "gobernadora" *Larrea tridentata*, "calabacilla de coyote" *Cucurbita foetidissima*, "caña agria" *Rumex hymenosepalus*, por mencionar algunas.

¹ Ponencia presentada en la Reunión Sobre Manejo de Plantas en Zonas Áridas. Saltillo, Coahuila, México. Febrero 18-22, 1985.

² Ing. COTECOCA-SARH.

La utilización más grande y peligrosa desde el punto de vista ecológico es sobre las plantas forrajeras, de las cuales se tiene aproximadamente una lista de 500 especies con mayor o menor grado de potencial alimenticio para el ganado doméstico y fauna silvestre.

Entre las principales especies se cuentan 381 spp. de 93 géneros de gramíneas entre perennes y anuales, de las cuales el 90% son forrajeras; 24 spp. de árboles y 53 spp. de arbustos, principalmente leguminosas y 16 spp. de hierbas perennes y algunas anuales.

Pero la problemática del uso de éstas plantas es la sobreutilización por sobrepastoreo que de ellas se ha hecho por años, a tal grado, que por regiones algunas de ellas ya han desaparecido, además de los daños antes mencionados, afectan la economía del mismo ganadero por baja producción de crías.

Tenemos estudiadas a fondo 7.3 millones de ha. del Estado a nivel predial y municipal y encontramos una erosión leve en el 21% moderada el 59% y grave el 20% de éstas superficies; la tendencia de erosión es de 70% negativa, 21% estabilizada y solamente el 9% positivo o a estabilizarse.

Este sobreuso por años tiene raíces de carácter agrario-legal y socio-económico y una falta de legislación y reglamentación adecuada,

práctica y fácil de aplicar, aunque en 1984 se hizo una nueva ley de ganadería en la entidad con un capítulo sobre la explotación, conservación, manejo y mejoramiento de los recursos forrajeros de los pastizales, ésta ley carece aún de reglamentación y no se ha podido aplicar por ésta carencia y factores socio-políticos.

También se carece de programas de extensión y educativos que penetren en la conciencia de los usuarios sobre el manejo más adecuado de sus recursos, así como de una investigación y experimentación, sistemática, masiva y de largo plazo sobre arbustivas forrajeras.

Si bien algunos centro de investigación de la zona han trabajado con gramíneas y algunas arbustivas, todas o casi todas son de introducción de otras partes del país o del extranjero, pero no se ha hecho nada o casi nada con la especies nativas.

Tenemos muchos trabajos y muy importantes y exitosos con zacate buffel Cenchrus ciliaris y podemos considerar que en Sonora ya esta naturalizado; con algunas especies de Atriplex, Kochia y otras se han hecho algunos trabajos de introducción y adaptación en la Península de Baja California, pero no conocemos resultados de producción y comportamiento bajo pastoreo y siempre se está tratando de buscar nuevas plantas forrajeras pero fuera de la entidad o del país.

Abstract.--The management of forage plants of the arid lands of Sonora is inadequate, and the utilization is excessive and destructive. Some forage plants may have other values and uses for the future, inclusive of sources of food for human consumption and industrial. There is a need for additional research and experimentation with native plants for awareness programs, education and training, and new techniques, especially those dealing with management, conservation and development of these biotic resources.

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**Weeds Common to Mexican and U.S. Rangelands: Proposals
for Biological Control and Ecological Studies¹**

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Abstract.--Several species of woody and herbaceous plants are serious weeds of rangelands in the southwestern United States and northern Mexico. Biological control by the introduction of organisms (especially insects) from other areas of the world (especially Argentina) is a possible method for controlling native species such as Gutierrezia, Baccharis, Flourensia, Larrea, Prosopis, Hymenoxys, Aloysia, Astragalus, Drymaria, Juniperus, Acacia, and introduced species of Tamarix and Salsola. From these species, targets for control are selected by considering the amount of damage caused, beneficial and ecological values, and potential for success. Weeds that presently seem acceptable both to the USA and to Mexico are Gutierrezia, Baccharis, Flourensia, Hymenoxys, and Drymaria; additional species could be considered if conflicts of interest can be resolved. Studies in the USA are determining the ecology of shrub invasion in grasslands, particularly by Prosopis, Juniperus, and Opuntia. Information is needed from Mexico on the harmful and beneficial values of each weed so that decisions can be made that are in the best interest of both countries.

INTRODUCTION

Several important weeds of rangelands occur in both northern Mexico and the southwestern United States. The possibility for biological control of some of these plants needs the careful consideration by scientists of both countries and decisions by both countries on whether and to what extent to proceed with a biological control program for each of the target weeds. The opinions and technical information is needed from Mexican scientists in ecology, botany, natural resources, rangelands, and livestock production. The objectives, philosophy, and potentialities for this project were discussed previously by DeLoach (1978, 1979, 1981, in press).

The present encroachment of brush into the rangelands of southwestern North America is the result of slow evolutionary changes throughout the vegetational history of the area and of rapid changes recently made by European man. The mesophytic, tropical forests of the Mesozoic Era gave way to large areas of savannah, grassland, and desert as the climate became more arid during the mid-Tertiary Period, ca. 25 million years ago, and the contest between herbaceous and woody species began. This contest culminated during the last 15,000 years with the retreat of the Wisconsin glacier and the continuation of a general drying trend, followed by the extinction of many species of large and small animals and the appearance of man (Smeins 1983).

Fire has been an important factor in the development of terrestrial vegetation, as is evidenced by the fossil record and by the occurrence of many fire-adapted species. Fire may or may not have created the grasslands but it almost certainly had a major influence on their character. Fire frequency varies from 2 to 25 years for most forested areas in dry climates and probably was at least that frequent in semi-arid grasslands (Komarek 1972, Smeins 1983).

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During the last 150 years in the U.S., the former grasslands have been rapidly invaded by brush in response to the introduction of grazing livestock by European man. This has caused a great reduction in the forage available for livestock grazing, and it has triggered large scale soil erosion and reduced soil water and stream flow (Humphrey 1958, Buffington and Herbel 1965, Harris 1966, York and Dick-Peddie 1969). This process began in Mexico perhaps 250 to 300 years ago. The greatest change has been the local invasion of native shrubs and herbaceous plants that are unpalatable or poisonous to livestock. None of these species have notably increased their geographic range but they have increased greatly in density (Johnston 1963, Inglis 1962).

The major causes of this recent "brush problem" in rangelands are thought to be overgrazing, spread of woody plant seed by livestock, reduced range fires, and reduced competition of grasses with woody plants, especially during seedling establishment. All of these factors are interrelated. Overgrazing reduces the grass cover below the level where it can carry a fire and weakens grasses so they are more damaged by periodic droughts than are shrubs (Bogusch 1952, Humphrey 1963, Wright and Bailey 1982). Mesquite and certain other large-seeded trees probably developed a strategy of survival based on seed dispersal by large herbivores that previously were abundant in both North and South America and became extinct about 10,000 years ago. These plants were not able to exploit this strategy again until European man introduced horses and cattle (Janzen and Martin 1982, DeLoach, in press).

Since the cause of the recent shrub invasion of grasslands is improper management of grazing livestock, one might suppose that proper management would correct the problem. However, in several experiments where plots were protected from grazing for periods of from 5 to 70 years, invasion by mesquite continued (Parker and Martin 1952, Smith and Schmutz 1975, Meyer and Bovey 1982). Apparently, shrubs must first be removed before much improvement can be made in forage production.

Livestock producers have been fighting shrub and poisonous plant invasion for many years. Mechanical controls such as hand grubbing, bulldozing, and root plowing were effective (Scifres et al. 1973, Scifres 1980) but in the United States are now too expensive to use except in small areas because of increased labor, machinery, and fuel costs. Herbicides such as 2,4,5-T have been used (Herbel et al. 1983) but are only marginally economical and do not always give good control.

Biological control is a different approach that has been used successfully in several areas of the world since the 1860's (Huffaker 1959; Freeman 1978; DelFosse 1981, 1985; Templeton 1982). It is not appropriate for all types of weeds but in those cases where biological control can be used it is highly effective, it gives permanent control (Huffaker 1959), and it is very low cost (Andres 1977, Harris 1979). The approach is to use insects, plant pathogens, or other organisms to control weeds. The objective is not to eradicate a weed species but to reduce it to a pest of lesser or of no economic importance (Huffaker 1959).

Major Approaches

Introduction of Foreign Control Agents

Introduction has been used to control many serious weeds in several countries of the world (Huffaker 1959, Goeden 1978, Julien 1982, Kelleher and Hulme 1984). DeBach (1974) reported that in the past 80 years 41 projects had been attempted worldwide, of which 75% had achieved a measurable degree of success: 8 were completely successful (no further control needed), 9 gave substantial, and 14 gave partial control. Until 1980, biological control by the introduction of exotic organisms had been tried against 86 weed species using 192 organisms (Julien 1982).

The approach is to find organisms (usually insects), near the center of origin or within the natural distribution of the weed that are capable of reducing weed populations (Huffaker 1959, Sands and Harley 1980, Wapshere 1980, Goeden 1983, Harris 1984). These insects then are tested in the overseas location, usually followed by further testing in quarantine in the country with the weed problem, to insure that they do not harm other plant species (Zwölfer and Harris 1971). Finally, the insects are released in the field and the results evaluated (Huffaker 1959, Wapshere 1975). The insects need to be released at only one or a few sites from which they reproduce and spread on their own and actively seek out the weed. The only cost is that of the research. The individual farmer or rancher has no cost.

The entire testing and release process is under careful review by all parties that might be affected including those of neighboring countries. Proposals from the United States are currently reviewed by the joint Working Group on Biological Control of Weeds of the U.S. Department of Agriculture and the U.S. Department of the Interior (Klingman and Coulson 1982, 1983). Prior to making their recommendation to the Animal and Plant Health Inspection Service (APHIS) of the USDA, the Working Group requests an opinion from Mexican and Canadian officials. In Mexico, these inquiries are sent to 1) Instituto Nacional de Investigaciones Agrícolas, 192

San Luis Potosi, Mexico D.F., and to 2) Direccion General de Sanidad Vegetal, Guillermo Perez Valenzuela 127, Coyoacan 21, Mexico D.F.

Augmentation of Present Control Agents

Recently a different approach to bio-control of weeds has been proposed, that of augmenting the effectiveness of the phytophagous organisms already present in an area, whether native or previously introduced. Frick (1974) reviewed the various methods of augmentation that have been used. These methods include modifying the agro-ecosystem to the disadvantage of the weed, such as careful grazing management to increase competing vegetation. Also, methods of increasing the number of biotic suppressants attacking the weed have been used. These include distributing insects from areas of surplus or from laboratory colonies grown on host plants or artificial diets, producing an inundative effect by using plant pathogens as "bio-herbicides," and using insecticides to reduce the parasites or predators that attack the bio-control agent (Frick 1974).

Recently, Frick and Chandler (1978) mass released the moth, Bactra verutana, from laboratory colonies to control Cyperus rotundus in cotton fields in Mississippi, USA. Releases of 5 larvae per weed shoot 3 to 5 times during the early growing season provided effective control that resulted in a normal yield of cotton. However, the cost of mass rearing so many insects would not be competitive in cost with commercially available chemical herbicides; in addition, large rearing facilities and an intricate distribution system would be required. This method appears practical only for very high value crops such as vegetables and flowers or for hobby gardeners where economics may be secondary to aesthetic or environmental goals. However, augmentation might be more practical in Mexico, where labor costs less and herbicides cost more, than in the U.S.A.

Plant pathogens also have been used to control weeds in crops (Templeton 1982). For example, in the southern United States, integrated control systems have been developed to control three weeds in rice fields and certain weeds of cotton and soybean fields using naturally occurring plant pathogens as bio-herbicides (Smith 1982). The cost of augmentation is dependent on the area treated and the duration of the treatment. Treatments must be applied to every infested hectare to be controlled and the treatment must be applied periodically, usually at least once a year. The reason is that the treatments probably will increase the population of these insects for only a short time. The native insects are always present at populations that vary from place to place and from year to year in response to local variations in temperature, rainfall, and their own natural enemies. Without augmentation, the amount of control produced at present is about all that can be expected.

In rangelands, most methods of control by augmentation appear to be too expensive because the production per unit area is very low. Rearing sufficient numbers of insects to control weeds on 6 to 20 ha to produce 1 cow per year cannot be economical to the rancher. Plant pathogens are much cheaper to mass rear than insects but still may be too expensive for controlling weeds in rangelands because of application costs.

Ranchers who hear of biological control of weeds by using insects frequently propose that researchers should increase the effectiveness of a variety of native insect species that they have observed damaging the weed at certain times. They reason that with sufficient research these native insects could be made effective every year and in all locations. Technically, they may be correct. However, the methods that could be used are expensive; also, the theory of density dependency between insects and their parasitoids and pathogens states that the more insects we release the higher will be the percent mortality of these insects from their natural enemies. The point of diminishing effectiveness would probably be reached long before the weed was controlled.

Comparison of Control Methods

Herbicides.--The greatest advantage of herbicides is their broad spectrum and effectiveness against many weed species. One application will often control all, or most, of the weeds in a particular agricultural system; also, application can be limited to a given area. Cost is dependent on the area treated and the duration of the treatment. Total cost increases as more area is treated. Cost per hectare decreases to a point as more efficiency is gained through mass production and mass distribution (fig. 1). Herbicides are often too expensive for areas of low economic return such as rangelands, since the entire affected area must be treated periodically.

Biological Control.--Biological control, both by augmentation and introduction, has the advantage of being very species specific and of not harming non-target species. It causes no chemical pollution of the environment and, sometimes, it can control species difficult to control by other methods. Because of its high specificity, it is most useful in areas where only one weed species causes most of the damage. A major restriction is that we cannot find insects suitable for controlling every weed.

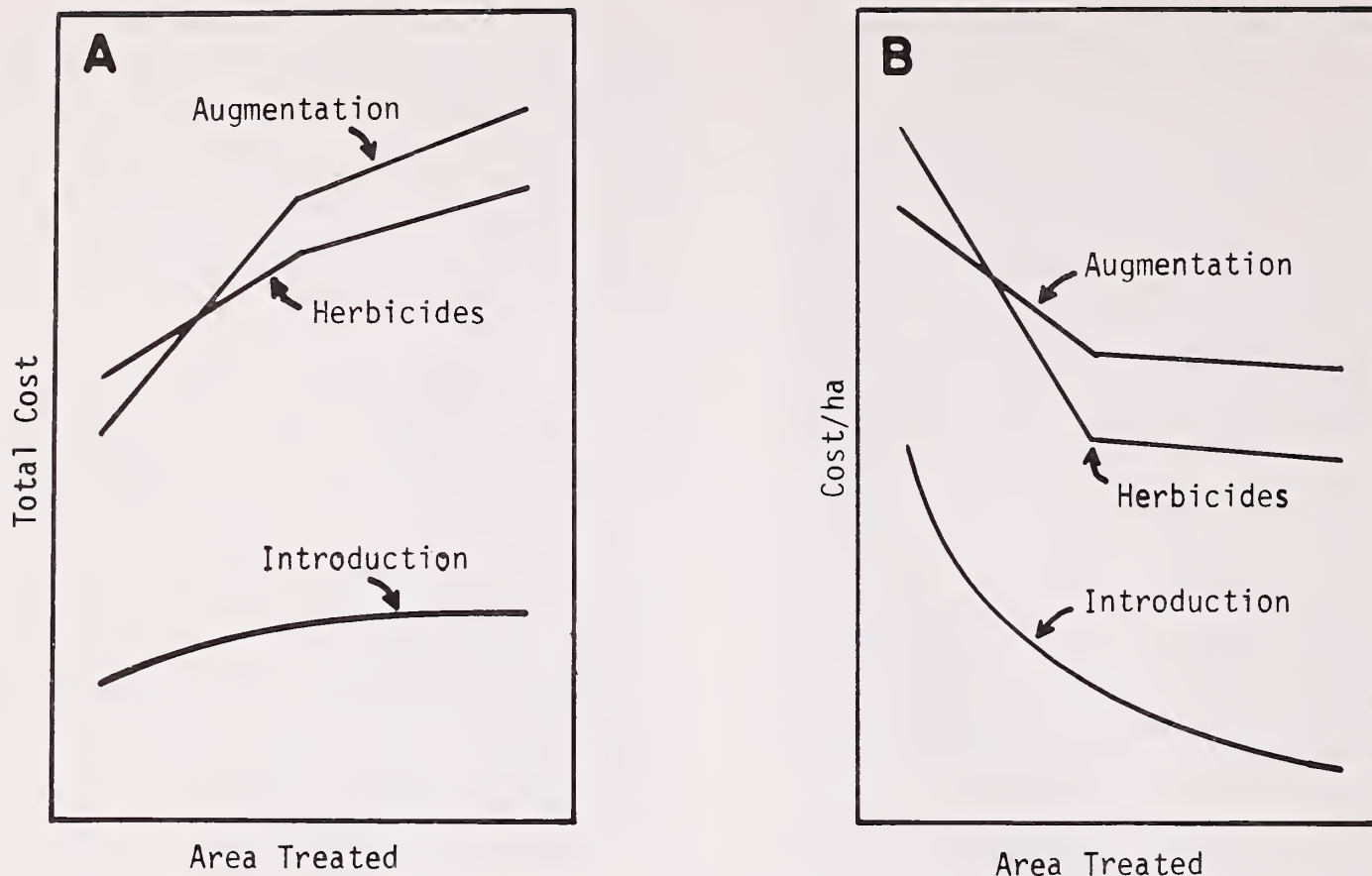


Figure 1.--Comparison of relative cost of herbicides and biological control by augmentation or introduction with increasingly larger areas treated: A) total cost of control, B) cost per hectare.

The greatest advantages of augmentation over introduction are that it is effective only in areas where applied and so does not damage beneficial uses of the plant; also, its effect can be ended simply by discontinuing application. It is similar to herbicide use in that the entire affected area must be treated at repeated intervals and so cost is dependent on the area treated and the duration of the treatments. Total cost and cost per hectare may be greater, or less, than herbicides, but the trend is the same (fig. 1). Augmentation is unlikely to be economical in areas of low economic return such as rangelands.

The greatest advantages of introduction over other methods are that control is permanent and the cost is independent of the area treated. The cost of a program is only that of the research and distribution of the organisms, and the individual farmer or rancher pays nothing. Research costs for controlling one weed species are about \$1-2 million in the U.S., or ca. 15 scientist years (Andres 1977). Total cost of a program remains constant regardless of the area treated, but cost/ha decreases as larger areas are controlled, and decreases still more with each added year of control (fig. 1). This makes the method very applicable to areas of low economic return, such as rangelands. A disadvantage of introduction is that the control organisms are likely to attack the weed species in areas where it has beneficial value.

Considerations in Using Biological Control

Control of Native Plants.--Most of the more serious weeds of southwestern rangelands are native species. Biological control of native weeds may be more difficult than for introduced weeds because:

- 1) Control organisms that are sufficiently host specific for introduction may be more difficult to find.
- 2) A native weed is more likely to be closely related to beneficial native species, making host specificity of control organisms more critical.
- 3) Most niches through which a control organism could attack the weed may already be occupied.
- 4) The weed species, and its close relatives, are more likely to be of value in the ecosystem.

The classical approach to biological control of introduced weeds has been to introduce the insects (or plant pathogens) from near the site of origin of the weed that naturally control its populations there. With native weeds, this approach obviously cannot be applied; the insects that evolved with the weed are already here and produce the degree of control we now see.

However, several of our native weeds are from genera that have species native in other areas of the world, especially in southern South America. We propose to introduce natural enemies, especially insects, from South America to control certain weeds. The principle criteria for success are that the weed should not have overriding beneficial values and that natural enemies can be found that damage the plant but yet are sufficiently host specific not to damage beneficial plants if introduced here. Several of the major weeds of southwestern U.S. and northern Mexico have reasonably good potential for successful control.

Some biological control workers have expressed concern that control of native weeds might trigger some unknown and unwanted reaction in the ecosystem that might be of serious consequence (Andres 1981). However, one of us (Johnson, in press) examined (from the perspective of plant ecology) the effects of species removal on the ecosystem. He found little or no evidence in past catastrophic reductions of dominant native species, in past biological control successes, or in ecological theory to indicate that significant harm might occur to ecosystem function. Also, in all cases of major successes in biological control throughout the world, low populations of the weed remain; no weed nor non-target plant species has been pushed near an endangered status.

Conflicts of Interest.--A plant that causes damage in one situation, for example on rangelands used for livestock production, may provide benefits in other situations, such as for ornamental shade trees, for human food, emergency livestock grazing, or for wildlife food and cover. Conflicts of interest between groups who regard plants differently is one of the major problems that must be resolved before beginning a project on biological control. In this paper, we present briefly the harmful aspects, beneficial values, ecological values, and the potential for successful biological control of several target weeds. More detailed analyses of each weed are either being published (DeLoach, in press) or are in preparation. The purpose is to provide a basis for discussion between groups with conflicting interests so that decisions eventually can be made about whether or not to attempt biological control of each candidate weed species.

Proposed Species for Biological Control

We have attempted to prepare a list of priority weeds for biological control research. The criteria for selection were, 1) The weed causes sufficient damage to justify the cost of a control project; 2) The weed species, or other species of the weed genus, grows as a native plant in some other area of the world where we would have a chance of finding control organisms; 3) Neither the weed species, nor its close relatives, are of overriding beneficial value; 4) Control organisms are known that appear capable of controlling weed populations.

Gutierrezia (Snakeweed, Escobilla)

The genus Gutierrezia (Compositae: Astereae) consists of annual and perennial shrubs that originated in southwestern North America, probably in montane habitats of the southern Sierra Madre Occidental of Mexico, possibly during the Miocene (Lane 1980); she recognized 16 species in North America (Lane 1985). The genus subsequently spread to southern South America, probably by long-distance dispersion by birds, where 11 species subsequently evolved; all are higher polyploids of the North American species and all are perennials (Solbrig 1966). The genera Gutierrezia, Xanthocephalum, Amphiachrys, Gymnosperma, and Grindelia are all closely related (Lane 1982).

The most serious weedy species are the perennials, Gutierrezia sarothrae and G. microcephala, which together infest 58 million ha in the U.S. (Platt 1959) and more in Mexico; both are toxic to cattle. The annuals G. sphaerocephala, G. texana, and the closely related Amphiachrys dracunculoides, are also serious weeds but are not toxic.

Gutierrezia was an uncommon plant 150 years ago and its recent great increase in density was probably caused by overgrazing. The greatest damage occurs in New Mexico, Chihuahua, and Texas; over vast areas it is now the dominant plant, often with little grass remaining (Humphrey 1958). It is also toxic and in affected herds of cattle, 10-60% of the calf crop may be born dead, weak, or premature (Dollahite and Anthony 1956). The annual species interfere with grazing, causing reduced calf growth rates.

Gutierrezia has very little beneficial value either for commercial utilization or for wild mammals and birds (Martin et al. 1951).

We have found several root-boring insects in Argentina that severely damage the tap roots (Cordo and DeLoach, in press b). The most important are Heilipodus ventralis (Coleoptera: Curculionidae), Carmenta haematica (Lepidoptera: Sesiidae), and Dactylozodes alternans, D. okea, and Agilus leucostictus (Coleoptera: Buprestidae). In Argentina, one of us (Cordo, unpublished data) found that H. ventralis attacks Gutierrezia and Grindelia chiloensis about equally and attacks Baccharis slightly. Testing is continuing in quarantine at Temple, TX, and testing is now underway in Argentina on C. haematica.

Baccharis (Seepwillow, Jara)

Baccharis (Compositae: Astereae) is a genus of ca. 400 dioecious species native only in the Western Hemisphere; the center of origin is South America (Cuatrecasas 1967, Barroso 1976). About 27 shrubby species occur in Mexico and 21 in the U.S. (Haseler 1969, Shelter and Skog 1978).

Baccharis infested 81,720 ha in Texas in 1973 (unpubl. records, USDA Soil Conserv. Serv., Temple, TX); it occupies additional areas in New Mexico, Arizona, southern California, and northern Mexico. Baccharis species are problem weeds of rangelands, pastures, parks, recreational areas, and flood plains of streams. Baccharis species are unpalatable to livestock and form dense thickets as phreatophytes along streams, crowding out valuable forage plants (Parker 1972). Baccharis species produce large amounts of seed, rapidly invade abandoned cultivated fields and other disturbed areas, and resprout if cut off above ground. Control with herbicides is generally too expensive relative to the low value per unit area of rangelands. Problems caused by the 3 most important weedy Baccharis species are as follows:

Baccharis salicifolia (= B. glutinosa) is one of the dominant phreatophytes along streams and flood plains, reservoirs, and irrigation and drainage canals. The plants cause increased sediment deposits in streams and reduced water flow, and thus contribute to flooding, increased canal maintenance costs, and loss of enormous quantities of soil water in areas where water is scarce and needed for other purposes (Timmons 1959, Parker 1972). In 1953, undesirable phreatophytes as a group covered 4,453,000 ha of bottomland in 14 western U.S. states and used nearly 20.6 million megaliters of water (16.7 million acre feet) (Fletcher and Elmendorf 1955).

Baccharis halimifolia is toxic to some animals (Duncan et al. 1957) and is probably a cause of hayfever in humans (Wodehouse 1971). It rapidly invades areas of recent soil disturbance and is common along roadsides, along drainage ditches, in abandoned cultivated fields, etc. (Haseler 1969).

Baccharis neglecta has become a management problem in rangelands and pastures in the southern half of Texas. It rapidly invades productive disturbed land and grows rapidly, forming dense stands (Mutz et al. 1979, Scifres 1980).

Baccharis species have few beneficial values and none of these values appear to be of widespread importance. Baccharis halimifolia is used as a garden shrub or hedge in Florida because of its hardiness, freedom from disease, attractive fall flowering, and resistance to salt spray (Haseler 1969). Baccharis salicifolia is sometimes used for erosion control (Vines 1960) although Fletcher and Elmendorf (1955) suggested the use of other plants that use less water. All 3 species are locally considered to be good honey plants because they flower in late summer when few other plants are in flower. The amount of honey produced varies greatly from year to year (Pellett 1930). The only species used commercially in the U.S. is B. pilularis, a low-growing shrub used in California around houses and on roadbanks as a ground cover. It maintains a bright green color during the dry season, forms a dense mat that

excludes most weeds, and withstands full exposure to the summer sun (Munz 1949).

Baccharis has little or no value for wildlife except for the cover it provides and possibly as nesting sites for songbirds (Tarver et al. 1979). It is not listed as a food for any wildlife by Martin et al. (1951).

Several insects have been found attacking Baccharis in Brazil (McFadyen 1979) and Argentina (H. A. Cordo, unpubl. data) and some of these have been released in Australia for biological control of the introduced B. halimifolia, the only species that occurs there. Three species of insects are currently under investigation for biological control by one of us (Boldt) in the Insect Quarantine Facility at Temple, TX.

Megacyllene mellyi (Coleoptera: Cerambycidae) is a stem borer from Brazil that requires living tissue for development. The larvae tunnel under the bark for about one month before feeding toward the center of the stem. Small plants have been killed by as few as 2 larvae tunneling in the base (McFadyen 1979). This beetle was released in the field in Australia in 1978 and is now well established there.

Rhopalomyia californica (Diptera: Cecidomyiidae), native in California, produces galls on the growing tips of the branches. Many galls can severely stunt the plant and retard growth. This gall midge was released in Australia in 1982 where it is increasing rapidly. It appears capable, with more time, of providing good control there (McFadyen, in press).

Anacassis spp. (Coleoptera: Chrysomelidae) are native in Argentina and Brazil. They are leaf feeders in both the larval and adult stages. These insects are multivoltine and occur in large numbers in Argentina. Anacassis fuscata was released in Australia but has not provided much control of B. halimifolia there. Preliminary tests at Temple, TX, show that they are very host specific and will probably attack only B. salicifolia to any significant extent.

Larrea (Creosotebush, Gobernadora)

The genus Larrea (Zygophyllaceae) originated in Argentina and spread to North America, probably by birds, as recently as 10,000 to 14,000 years ago. Only one species occurs in north America, L. tridentata, which is very close taxonomically to the Argentine L. divaricata (Hunziker et al. 1977).

Larrea occupies an estimated 19 million ha in the U.S. (Platt 1959) and over 10 million ha in northern Mexico (González 1971). It has spread greatly in the last 150 years into previous grasslands, apparently as a result of overgrazing by livestock (York and Dick-Peddie 1969). In the arid areas where it is abundant, it is now the dominant species over large areas.

In many areas, very little grass remains. Recent studies in New Mexico have shown that seriously denuded areas can be returned rapidly to good stands of native grasses if Larrea is killed with herbicides and the grass is not overgrazed (Melgoza et al. 1984). The foliage of Larrea appears not to be toxic but is not palatable to livestock.

Larrea has been extensively investigated in Mexico for possible industrial utilization (Campos-Lopez et al. 1979). Large amounts of the phenolic compound nordihydroguaiaretic acid (NDGA) are present in the resin on the external surface of the leaves and stems. NDGA is an antioxidant that has been used to retard rancidity of food products (Oliveto 1972). However, rats fed NDGA at 3% of the diet developed kidney cysts and it was banned as an additive in food by the U.S. Food and Drug Administration (Timmerman 1977). NDGA is also an effective antioxidant to stabilize rubber, perfume oils, and other products. It has fungicidal activity, inhibits enzyme systems, and has some anti-tumor activity. Tea made from the plant has long been used as a folk medicine in both North and South America.

A total of 28 species of small mammals were found in Larrea communities in Arizona, from 6 to 13 species in each community, but only a few were very abundant, including Dipodomys merriami, Perognathus longimembris, P. penicillatus, and Lepus californicus. Also, 9 species of lizards were found (Mares and Hulse 1977, Blair 1979). None of these species appeared to be strongly dependent on Larrea. Reptiles, amphibians, and most other terrestrial vertebrates usually are not intimately associated with a specific plant taxon but sometimes are restricted to a specific plant community (Mares and Hulse 1977).

Fewer insect species appear to be associated with Larrea than with some other plants of semiarid areas such as Prosopis. Schultz et al. (1977) found 22 herbivorous insect associates of Larrea near Silver Bell, Arizona, 18 of which were monophagous. However, in a later paper discussing the same insects, Schultz (1979) listed only 7 species as monophagous. Hurd and Linsley (1975a) found 79 species of insects other than bees on Larrea in the southwestern U.S., 44 of which were abundant or common, but only one species of grasshopper and a few geometrid larvae were mentioned as possibly being restricted to Larrea. They also found 90 species of bees associated with Larrea, 22 of them oligoleges (Hurd and Linsley 1975b).

In Argentina, the insect associates also are not numerous but a few species occur there that appear to be host specific and might be suitable for introduction for biological control. Schultz et al. (1977) listed 19 herbivorous insects from L. cuneifolia near Andalgalá, Catamarca, Argentina, 5 of which were monophagous, and 3 that were oligophagous and fed only on Zygophyllaceae. The most damaging was the oligophagous grasshopper, Astroma quadrilobatum.

Also, 2 meloid beetles fed on flowers, the larvae of 2 buprestid beetles tunneled in the stems (Schultz et al. 1977, Schultz 1979), and scale insects fed on the stems and leaves (Teran 1973). A fossorial rodent, the tuco-tuco (Ctenomys fulvus), fed extensively on the stems and killed many plants in Argentina (Mares and Hulse 1977, Blair 1979); however, its food preferences and the effects of its burrows in rangelands would have to be carefully studied before considering it for introduction.

Tamarix (Saltcedar, Pinabete)

Tamarix (Tamaraceae) is a genus of ca. 54 species native from North Africa and the Mediterranean area to Pakistan (Baum 1978, Zohary 1972). About 7 species were introduced into the U.S. in the early 1800's as ornamentals. They have escaped cultivation and are rapidly invading the floodplains of southwestern streams. Tamarix spp. form dense thickets that use large amounts of water in this semiarid area where water is scarce, they contribute to sedimentation and flooding of the streams, and they replace the native vegetation (Watts et al. 1977, Van Hylckama 1970, Blackburn et al. 1982).

Tamarix has beneficial value as habitat, but not food, for the white-winged dove, Zenaida asiatica (Scudday et al. 1980), which occurs from southwestern Texas and southern New Mexico and Arizona southward through Mexico to Guatemala. In western Texas, saltcedar communities supported fewer bird species than did native plant communities (Anderson et al. 1977). In Mexico, the white-winged dove is thought not to be particularly associated with saltcedar; the areas with the highest dove populations have but little saltcedar (Lucio Rodríguez, Dept. Recursos Naturales, Univ. Autónoma Agraria "Antonio Narro," Saltillo, Coah., pers. commun.). Also, the flowers are an important source of nectar for honey production. One species, Tamarix aphylla, grows to a large size and is used as an ornamental shade tree in the southwestern U.S. and northern Mexico; it is also used as a windbreak in some areas.

Watts et al. (1977) collected 159 species of insects and one mite from Tamarix in New Mexico. Most of these species occurred only in very low numbers, with little evidence of feeding, and damage occurred only in isolated instances. Two alien insect species, a leafhopper Opsius stactogalus and a scale Chionaspis etrusca, were often abundant and damaged the plant.

The insects attacking Tamarix in its native range have been much studied. Gerling and Kugler (1973) listed 115 species of insects and 4 mites from Israel, Turkey, Iran, and Pakistan. Lozovoi (1961) listed 52 insect species from Georgia, U.S.S.R.; Zocchi (1971) listed 92 species from Italy, including 42 monophagous ones; and Pemberton and Hoover (1980) listed 26 species from Turkey. Gerling and Kugler (1973) studied the biology of 24 species

and concluded that 13 species would be good candidates for introduction. Species such as Ornativulva versicolor (Gelechiidae), Cryptocephalus fulgurans (Chrysomelidae), Naiacoccus minor (Pseudococcidae), Dasyneura tamaricina (Cecidomyiidae), Agdistis tamaricis (Pterophoridae), and possibly Lepidogma sp. (Pyralidae) attack the foliage of other species of Tamarix, but do not attack T. aphylla, and therefore would not harm ornamental T. aphylla plants or flowers used for honey production. Other insects also attacked T. aphylla, such as Sterapsis squamosa (Buprestidae), Semiothisa aestimaria (Geometridae), Oxyrrhachis versicolor (Cercopidae), and Opsius spp. (Cicadillidae). Other insects damage the flowers, such as Coniatus spp. and Corimalia spp. (Curculionidae), and Crastina tamaricina (Psylloidea).

We propose that a series of insects should be introduced from Asia in an attempt to obtain ca. 50% reduction in stands of Tamarix. At that time a reevaluation should be made to determine the effect on the dove-hunting and honey industries. A 50-80% reduction in stands would allow the reestablishment of much native vegetation, would conserve large amounts of water, and would cause little harm to the beneficial uses of the plant. Insects would be selected that do not attack or that caused only minimal harm to T. aphylla and that do not directly attack the flowers.

Prosopis (Mesquite)

The genus Prosopis (Leguminosae) underwent its greatest speciation in southern South America, where 33 species occur; 9 species are native in the U.S. and Mexico (Burkart 1976). The genus apparently spread to North America about 25-36 million years ago, in the mid-Oligocene (Smeins 1983). Two species, P. glandulosa and P. velutina, are probably the most damaging of all weeds in rangelands of the southwestern U.S. During the last 150 years, mesquite has invaded much of the former grasslands and has increased greatly in density, probably because of overgrazing, spreading of seed by livestock, and reduction in range fires. Mesquite causes damage by reducing forage production, increasing the cost of managing livestock, and reducing water available for agriculture, industry, and urban use (Smith and Rechenstien 1964, Rechenstien and Smith 1967, Fisher 1977, Scifres 1980). DeLoach (in press) estimated that mesquite causes direct losses to the livestock industry of \$200 to 500 million annually in the U.S. plus an unknown amount in Mexico; the amount of damage was probably 20-30 times greater than all present beneficial uses.

Control of mesquite by mechanical and chemical methods is expensive and only marginally effective. The most economical herbicide was 2,4,5-T; it had to be applied ca. once every 8 years and was cost-effective only on the denser stands on the more productive soils (Dahl et al. 1978, Whitson and Scifres 1979). It has

recently been prohibited for use. The new herbicide, clopyralid, promises to be more effective than 2,4,5-T (Jacoby et al. 1981) but will also be more expensive and relatively ineffective on associated weedy species.

Mesquite also has many beneficial uses (Parker 1982, DeLoach, in press). It is widely used throughout central Texas and southern Arizona as an ornamental shade tree for which its one-time value is approximately \$100 million in Texas. It is currently popular for barbecue wood and firewood for heating. It is an excellent source of nectar for honey production, and the legumes (beans) are eaten by livestock. In Mexico, the beans are collected, ground, and used in livestock feed, and the wood is used for firewood, farm construction, flooring, etc., although this usage has declined greatly in recent years because most of the larger trees have been cut (Gómez Lorence et al. 1970).

Other proposed uses for mesquite include production of paper, gums, chemicals and medicines, the processed wood for livestock feed, and the beans for human food. Production of these products from mesquite does not seem economically competitive with production from other raw materials that are plentifully available (Parker 1982, DeLoach, in press).

For a native plant that is so abundant over a large area of southwestern North America, mesquite has surprisingly little value for native mammals and birds. Mares and Hulse (1977) observed that more animals had an obligate relationship with mesquite in South America than in North America. One suspects that some species that once depended heavily on it are now extinct.

Mesquite constitutes 30-50% of the diet of jackrabbits (Lepus spp.), 30% of the diet of the wood rat (Neotoma albigula), 4-13% of the diet of the pocket mouse (Perognathus sp.), 4-11% of the diet of kangaroo rats (Dipodomys spp.), and 10-25% of the diet of the Gambel quail (Lophortyx gambelii). Mesquite was of little importance in the diets of other native mammals and birds (Martin et al. 1951). A drastic reduction of mesquite density would probably reduce populations of these animals somewhat; however, most of these are so abundant now that they cause damage to some rangelands and some reduction in their population might be advantageous. The Gambel quail is the only one of these species for which a reduction in its population would be undesirable; however, the amount of reduction caused by the degree of control we are likely to achieve probably would be relatively unimportant to quail populations (DeLoach, in press).

The cultivation of high-biomass producing strains of mesquite has been proposed as an energy source for production of electricity or petrochemicals (Felker 1984). Also, Gilbert (in press) speculated that nitrogen fixation by mesquite might be of great value in natural ecosystems and in rangelands. Neither of these

hypotheses have been demonstrated in the field. DeLoach (in press) suggested that nitrogen fixation may be inconsequential in upland areas and that sufficient biomass for commercial electrical production probably can be realized only with irrigation, in areas with a high water table, or in limited upland areas of highest rainfall.

Ward et al. (1977) listed 657 species of phytophagous insects collected from mesquite in the U.S. and Mexico. Cordo and DeLoach (in press a) reported 394 species of insects collected from mesquite in Argentina and Paraguay, 15 of which are cosmopolitan and also occur in North America. They concluded that 38 species were reasonably good candidates for further study for introduction into North America for biological control; these included insects that attacked the seed, flowers, buds, foliage, limbs, and trunks. Some of these insects caused extensive damage in Argentina and might be even more damaging if freed of their own natural enemies before being introduced here.

We tentatively propose that seed, legume, and flower feeding insects be introduced for biological control. Huffaker (1959) suggested that seed-feeding insects of long-lived perennial plants were unlikely to be effective bio-control agents. However, Neser and Kluge (in press) recently reported that the shrub, Hakea sericea, was being controlled by a seed-feeding weevil in South Africa. Harley (in press) discussed several projects where seed-feeding and flower-feeding insects are being used for control of woody plants. If effective, these insects that would reduce the reproductive capacity of mesquite would slow or halt its continued spread without harming its beneficial uses for shade trees, firewood, or energy production.

Flourensia (Tarbush, Hojasen)

Flourensia is a genus of 31 species of desert shrubs in the family Compositae (tribe Heliantheae), that probably originated in North America. Today, 13 species are found in North America (Mexico and adjacent areas of the U.S.) and 18 in South America (mostly in Argentina and Peru) (Dillon 1984). One species, F. cernua, is a weed in rangelands in the southwestern U.S. and northern Mexico and the acreage infested is increasing (Buffington and Herbel 1965). Its effect in rangelands is similar to that of Larrea. It grows intermixed with Larrea and stands are often invaded by Larrea, but it reaches its best development on heavy soils that receive some extra water (Gardner 1951). The ripe fruit is poisonous to sheep and goats (Kingsbury 1964). Flourensia cernua has no known important beneficial values to man or in plant and animal communities.

In our rather limited collections in the USA, we have found few insect species on the plant, although buprestid beetles occasionally bore in the stems and roots. In Argentina, we

have found rather numerous cerambycid and lepidopterous larvae boring in the crown and stems and weevils that feed on the foliage (H. A. Cordo and C. J. DeLoach, unpubl. data). Additional exploration for and testing of insects is needed in Argentina before the potential for control can be properly evaluated.

Hymenoxys (Bitterweed, Hierba Amarga)

Hymenoxys (Compositae: Helenieae) is a genus of about 28 species found only in the Western Hemisphere. The center of origin is southwestern North America. The genus spread to southern South America probably in the late Tertiary or Quaternary Periods and 4 annual species are native there (Sanderson 1975).

Two species are poisonous to livestock, especially to sheep. The perennial H. Richardsonii is a pest mostly in Arizona, New Mexico and Colorado, though it occurs to southern Canada. The winter annual H. odorata occurs from northern Mexico to Kansas but is a pest mostly in the Edwards Plateau of Texas. It becomes abundant only in occasional years when the seed germinate in the fall in response to fall rains. Most poisoning occurs in early spring when bitterweed is one of the few green plants present. In most years it grows only in wet depressions (playas) but spreads over wide areas in years of favorable rainfall. In the early 1930's more than half of many flocks died from bitterweed poisoning and heavy losses occurred again in the 1950's (Parker 1936, Cory 1951, Rowe et al. 1973). Annual losses in Texas were estimated at \$3,570,000 (Jaggi 1962). The nectar is very bitter and a small amount collected by bees can ruin a honey crop. Hymenoxin from bitterweed is mutagenic to some organisms; MacGregor (1977) discussed the possible dangers of livestock transmitting mutagenic compounds to humans through milk or meat.

Hymenoxys has very little beneficial value. Five species of the genus are minor ornamentals (Bailey and Bailey 1976), some of the chemicals in it have anti-tumor activity, and the latex was used as a minor source of rubber during World War II. Wildlife do not use any species of the genus as food (Martin et al. 1951).

We have found a few insects in Argentina that may hold promise for biological control. The most promising are an unidentified species of Diptera whose larvae feed in the petiole and crown and two species of Lepidoptera whose larvae feed in the crown and roots.

Salsola spp. (Russian Thistle, Tumbleweed)

Salsola (Chenopodiaceae) is a halophytic, desert genus of ca. 150 species of cosmopolitan distribution. Two species of Russian thistle are present in North America, both introduced from Asia. Salsola iberica (= S. pestifer or S. kali) is more prominent at the higher elevations

and latitudes of the USA and S. paulsenii is more prominent at lower elevations of the southwestern area (Beatley 1973). Russian thistle was introduced into the USA in 1873 as a contaminant of flax seed that was planted in South Dakota. It has since spread over most of the central and western USA and northern Mexico.

Russian thistle infests 41.3 million ha in the western USA (Platt 1959). It occurs mostly in disturbed areas such as highway rights-of-way and abandoned cultivated fields but seldom invades rangelands. At maturity, the plant breaks off at the base and rolls in the wind. The dead plants pile up along fences and buildings creating a fire hazard, interfering with fence maintenance, and causing a nuisance. Older plants are unpalatable to livestock and physically inhibit grazing although they are not poisonous. Russian thistle is the primary host of the beet leafhopper, Circulifera tenellus, which is the vector of "curly top" virus of sugar beets, tomatoes, and cucurbits (Lawson and Piemeisel 1943) and it is an important weed in winter wheat.

Russian thistle has very little beneficial value. Young plants are sometimes grazed by livestock and it has been proposed as a drought resistant forage plant and a source of biomass for fuel. During the drought of the 1930's, 400,000 tons were harvested for hay in western Kansas in 1934 (Hageman et al. 1978).

The seeds of Salsola are eaten by 8 species of birds. The foliage and seeds are eaten by 11 species of small mammals and by deer, elk, and antelope; however, it constitutes as much as 10-25% of the diet of only the prairie dog (Cynomys sp.) (Martin et al. 1951).

Many species of insects have been found attacking the plant within its native range in the USSR (L. A. Andres, pers. commun.), in Pakistan (Baloch et al. 1975), and in Turkey (Goeden 1973). However, only a few of these were host specific. Two species of moths (Coleophoridae) have been released in the USA, Coleophora parthenica that tunnels in the pith of the stems and C. klimeschiella that feeds on the foliage (Hawkes and Mayfield 1978). Coleophora parthenica has become well established and abundant but causes little damage to the plant (Pemberton 1980); C. klimeschiella also causes little damage (L. A. Andres, pers. commun.). A third species, Heterographis monostictella (Lepidoptera: Phycitidae) appeared host specific in the field but completed its development on beet in laboratory tests (Baloch et al. 1975).

The two insects, Coleophora parthenica and C. klimeschiella could be released in Mexico for control of Russian thistle. So far they have been ineffective in the USA, but the longer growing season in Mexico might allow them to develop additional generations each year thus producing larger populations and a greater degree of control. Additional exploration is needed in areas of the USSR and China to find

additional host-specific natural enemies for introduction into North America.

Aloysia (Whitebrush, Jasmin)

Aloysia (Verbenaceae) is a genus of about 30 species that originated in southern South America and is restricted to the Western Hemisphere. Seven species occur in Mexico and the U.S. (Botta 1979, Troncoso 1974). Aloysia gratissima (= A. lycioides) is the only weedy species of importance; it is apparently native in Mexico and the southwestern U.S. but presumably evolved in Argentina and Paraguay since it also occurs naturally there.

Aloysia is a pest mainly because it competes with forage plants and forms dense thickets that make handling livestock difficult. It occupies ca. 3 million ha in the U.S. with ca. 350,000 ha in dense stands. It is a pest mostly in central and southern Texas, often on the best soils. Forage production is usually increased 2-3 times by controlling whitebrush. Rootplowing, raking, and double disking give good control but are too costly; tebuthiuron gives effective control at rates of 0.5 to 1.0 kg/ha. We estimate that direct losses to livestock production are ca \$25 million annually.

Although whitebrush produces a premium, light honey, it produces a good yield only every 2 to 3 years. The Argentine A. triphylla is sometimes cultivated in the U.S. as an ornamental but A. gratissima is rarely if ever cultivated (Bailey and Bailey 1976). It is not a food plant for wildlife (Martin et al. 1951) and it is of little value as cover for deer (Inglis et al. 1978).

We have never found insects damaging the stems or roots of A. gratissima in Texas; the phytophagous insects collected from the foliage appear to be only incidentals, and we have found no pathogens. All niches for herbivorous insects appear to be unoccupied. However, the South American fauna on Aloysia is also poor, though greater than the North American. Cordo and DeLoach (in press c) collected 82 species of insects and 4 plant pathogens from Aloysia in Argentina, Paraguay, and southern Brazil.

The better candidates for introduction are a new species of rust fungus, Prospodium tumefaciens, that causes stem galls, a buprestid stem-boring beetle in the tribe Agrilini, a large cerambycid crown-boring beetle probably in the genus Calocosmus, a scale insect in the genus Cerococcus, a bark-feeding moth Timocratica sp., and a cerambycid twig girdler near the genus Arenicia (Cordo and DeLoach, in press c). Only the rust fungus caused much damage but the other species might cause more damage in North America if their own parasites were eliminated before release. Further study is needed in Argentina to determine if any of these organisms are suitable for introduction.

Other Weeds

Several other weeds of rangelands have potential for biological control but have been less investigated by us; conflicts of interest with beneficial values of some plants are too great to attempt control.

Several species of Astragalus (Leguminosae) (locoweed, yerba loca) are poisonous to livestock; losses from poisoning are estimated at \$10 million annually in the U.S. and an undetermined amount in Mexico. Astragalus is a genus of ca. 1500 species, mostly of Holarctic distribution, with 368 species native in the U.S. and about 87 in southern South America. The chances of finding insects that would attack our pest species are good. We have found insects in Argentina that damage the foliage, legumes, and roots of other species of the genus. However, several native species in North America are valuable for wildlife, several are rare or endangered, and a few are cultivated as forage plants. These conflicts would have to be evaluated carefully before considering a bio-control project.

Opuntia (Cactaceae) is a genus of ca. 187 spp, all from North and South America. Benson (1982) stated that the taxonomy of the genus is in a chaotic state. He listed 43 species of subgenus Cylindropuntia in the U.S. and Mexico and 42 species in southern South America. In subgenus Opuntia (prickly pear), he listed 48 species from the U.S. and Mexico, 23 species from southern South America, and 31 species from the West Indies, northern South America, Brazil, the Galapagos Islands, or of unknown origin.

Opuntia spp. (prickly pear, nopal) infest 31 million ha in the U.S. (Platt 1959); 15 million ha of this is in Texas, 1 million ha in dense stands (Smith and Rechenstien 1964). The most serious damage is to the sheep industry in central Texas. When sheep (or other animals) eat the pads or fruit, the spines and glochids become embedded in the mouth, esophagus, and stomach, causing weight loss and sometimes death. However, Opuntia also has considerable beneficial value: the fruits and young pads (cladophylls) are used as human food, it is widely used as an ornamental, and ranchers burn off the thorns and use it for supplemental grazing during droughts. It is recognized as a valuable forage for cattle in Mexico (González 1971). Also, 44 species of wildlife use it, and it is a major part of the diets of three species (Martin et al. 1951). Many of the North American species are beneficial and some are rare.

Several insects are known in Argentina that probably would give good control if introduced, including Cactoblastis cactorum (Lepidoptera: Phycitidae) that has been introduced elsewhere for successful cactus control (Dodd 1940). The beneficial values of prickly pear appear too great to attempt biological control. However, other species of Opuntia in subgenus Cylindropuntia, such as O. imbricata (tree cholla,

coyonostole) and O. leptocaulis (tasajillo) are serious pests and have little or no beneficial value. Biological control of these species perhaps could be attempted if control agents could be found that are sufficiently host specific not to attack the "pear" species or other beneficial cacti.

Juniperus (juniper or cedar, enebro) is a genus of about 70 species native throughout the Northern Hemisphere. Junipers infest 26 million ha (Platt 1959) and are among the most serious weeds of western and southwestern U.S. ranges; they are not poisonous but compete severely with forage plants (Smith and Rechenstien 1964, Scifres 1980). Junipers usually occur on poor range sites where chemical and mechanical control methods are too expensive. The native J. virginiana and possibly other species of Juniperus are alternate hosts for cedar-apple rust (Gymnosporangium juniperi-virginianae), a serious disease of fruit trees.

Several native and introduced species are widely used and valuable ornamentals, and J. virginiana is valuable for lumber for cedar chests and closets (Bailey and Bailey 1976). The weedy species of the southwestern United States are used for fenceposts and production of aromatic oils. Junipers are valuable plants for wildlife feed and cover; 44 species of birds and mammals feed on them but they are of major importance (more than 10% of the diet) for only 4 species (Martin et al. 1951). Previously, we have considered that Juniperus is too valuable to attempt biological control. In view of the severity of the damage caused, we believe the question should be re-examined. A more complete analysis of conflicts of interest should be made and surveys should be made to determine if suitable control agents exist.

Acacia farnesiana (huisache) (family Leguminosae) infests about 800,000 ha, mostly in southern Texas (Smith and Rechenstien 1964) and probably much more than this in Mexico. It forms thorn thickets on the better soils in low areas and competes with forage plants. Acacia is a large genus distributed throughout semiarid areas of the Southern Hemisphere. Huisache is valuable for firewood, farm implements, honey production (Gómez Lorence et al. 1970) and as a shade tree and occasionally as an ornamental. The conflicts of interest need to be evaluated to determine if biological control should be considered.

Drymaria (Alfombra) (family Caryophyllaceae) is a genus of 48 species, only 2 of whose ranges extend beyond the Americas. Two centers of speciation occur, one in Mexico where 31 species are native (7 of these extend into western USA), and one in southern South America where 17 species occur (15 in Peru, 7 in Bolivia, and 3 in Argentina). Only 4 species of the North American center occur in the South American center (Duke 1961). The annual D. pachyphylla is toxic to sheep and cattle; it occurs from southeastern Arizona, southern New Mexico, and western Texas south to western Nuevo

Leon, southern Coahuila, and eastern Durango. The perennial alfombrilla (*D. arenarioides*) occurs from Hidalgo and Guanajuato in central Mexico north almost to the United States border (Duke 1961; Hartman, in press). González and Martínez (1958) reported that alfombrilla was the most important toxic plant in Chihuahua and caused the death of over 1,000 cattle per year just in the north-central area of the state; however, it did not appear toxic to horses. Allison (1977) reported that it was poisonous to both cattle and sheep. Explorations are needed in the South American center of speciation to discover if natural enemies exist that could be introduced into North America for biological control.

CONCLUSIONS

Several of the more serious weeds of rangelands of the southwestern United States and northern Mexico have good potential for biological control. The introduction of insects and possibly plant pathogens from other areas of the world, principally from semiarid regions of southern South America, where other species of the weed genus are native, offer the most potential for success. Promising natural enemies have been identified on some of these weeds and a few insects are being tested at the USDA's Biological Control of Weeds Laboratory near Buenos Aires, Argentina, by one of us (Cordo). At the moment, the weeds that would seem acceptable to both the U.S. and Mexico for biological control are *Gutierrezia*, *Baccharis*, *Flourensia*, and several of the poisonous species. Perhaps more species can be added when the harmful, beneficial, and ecological aspects are more carefully analyzed.

Conflicts of interest between groups who regard a plant as a noxious weed and those who regard it as beneficial are a major consideration before initiating biological control programs. We are presently compiling the available information in the United States so that these conflicts can be equably and fairly considered. Then decisions can be made that are in the best overall interests of the two countries.

Most of the weeds under consideration are common to both the U.S. and to Mexico. When one considers the initiation of biological control programs, the interests of ranchers, small farmers, industry, and concern for a healthy ecosystem are of equal importance in Mexico as in the United States. So far, we have been able to gather only a little information from Mexico regarding the various aspects of these weed problems. The following types of information are needed:

- 1) A list of the most damaging weeds of rangelands.
- 2) Geographical occurrence of the weed and in which areas the greatest problems occur.

- 3) Estimated area (hectares) infested by each weed and density within the infested area.
- 4) Type of damage and estimates of economic losses caused by each weed.
- 5) Types of beneficial uses of each weed, both for commercial or home utilization and ecological values, and estimates of the value and importance of each.
- 6) References on the impact of each weed species in Mexico, especially on damage caused and beneficial, ecological, and wildlife values.
- 7) Opinions of Mexican scientists on whether or not biological control by introduction should be attempted for each target weed.
- 8) Priority listing of target weeds for biological control.

We would appreciate receiving any of this information from Mexican scientists, which can be sent to the senior author at the Grassland, Soil and Water Research Laboratory, USDA-ARS, P. O. Box 748, Temple, TX 76503. We would be happy to exchange any information or references at our disposal with Mexican scientists. When sufficient information is compiled, it should be analyzed by the scientists of both countries so that a joint decision can be made on whether or not biological control should be attempted for each target weed species.

ECOLOGICAL STUDIES

Woody plants are a natural component of most native rangelands but when overabundant they may greatly limit the amount of forage produced by nonwoody species. The increase of shrubs on western grasslands has taken place on so extensive a scale that it is sometimes viewed with alarm. Thus the occupancy of rangelands by woody plants is perceived as being "... the primary threat to effective use of rangeland in Texas and most of the southwest." (Scifres, 1980). The Soil Conservation Service (Smith and Rechenthin 1964, Hoffman, 1974) identified the "brush problem" as the number one problem of Texas grasslands. The Association of Texas Soil and Water Conservation Districts (1976) listed the problem of brush and weeds on rangeland as second only to taxation in severity. The Great Plains Agricultural Research Committee (1976) in a report entitled "Range Research Needs" recognized a particular need for understanding the ecology of weeds and brush in terms of life histories and population dynamics.

Rangelands are basically natural systems of complex structure and processes. Range management has the general goal of maintaining these systems in productive, predictable (stable) condition in the most efficient manner possible.

Thus, it is important that the components of the system be understood in terms of their relationship to each other and how they will respond to different kinds of management. The interactions among plants, the primary producers in the system, is a first order concern.

The recent observed increase in brush density is popularly ascribed almost wholly to recent abusive management practices, especially to overgrazing (Orev 1956, Buffington and Herbel 1965, Harris 1966). However, some observations suggest that brush increase may be due in part to natural processes that override human influence. The present increase may be a recurrence of a situation that prevailed hundreds or thousands of years ago (Carter 1964, Smeins 1983).

The general hypothesis on which brush research seems to be based either explicitly or implicitly is that brush (low value forage species) compete with herbs, principally grasses (high value forage species) for the essential resources, water, minerals, and light and that the elimination of low value brush will bring about a corresponding increase in production of the higher value forage species. Results reported in the literature from brush manipulation experiments do not support such a simple hypothesis of interspecific competition (Dahl et al. 1978) but instead suggest that other dynamic relationships among species (some positive, some negative) as well as changes in the physical properties of the environment are important (Tiedemann and Klemmedson 1973, 1977, Halverson and Patten 1975, Brock et al. 1978). The relative magnitude of the various positive and negative effects and their causal relationships need to be established.

Three types of plants that are serious weeds in rangelands of southwestern North America have been selected by one of us (Johnson) for ecological research at the Temple, Texas laboratory. Mesquite (Prosopis glandulosa), juniper (Juniperus ashei and J. pinchotii), and prickly pear cactus (Opuntia spp.) were selected because of their importance and because they represent extremes in adaptive strategies. Mesquite is a deciduous shrub with C-3 metabolism, it is a legume and is presumed to fix atmospheric nitrogen (Bailey 1976, Felker and Clark 1980), and it has roots at both moderate and extreme depths. Juniper is an evergreen shrub with conifer-type leaves, also with C-3 metabolism, it has both superficial and deep roots, and it produces strong allelopathic reactions with herbaceous plants. Prickly pear is a succulent with CAM metabolism, it has a very superficial root system, and it is not considered to be a strong competitor with forage plants although it can be a serious management problem (Martin and Tschirley 1969, Laycock 1983). All three types, mesquite, juniper, and prickly pear, are strong invaders of rangelands, particularly of overgrazed ranges.

Little is known about the basic biological processes, potentials, and strategies of the species involved. We are comparing the changes

in density between these shrubs and herbaceous species, as influenced by biological and physical factors, from three perspectives: 1) patterns of shrub invasion, 2) the spheres of influence of individual shrubs in the field, and 3) life history and physiological profiles of the shrubs. Also, we are documenting the similarities and differences between native weeds and naturalized exotics.

Changes in herbaceous production are seldom linearly related to the amount of mesquite removed and the pattern of herbage production after mesquite is killed does not correspond to mesquite reinvasion as should be expected if simple competition is all that is involved (Parker and Martin 1952, Dahl et al. 1978). The effect of juniper seems to be more consistent although much of this effect is ascribed to allelopathy in conjunction with competition (Jameson 1966). Our studies to date show that production of herbaceous plants is rapidly depressed by invasion of juniper.

Positive interactions on a local scale are commonly observed among shrubs and their associated plants. Several workers have observed greater herbaceous growth in zones under mesquite trees than in the areas between trees (Halverson and Patten 1975, Tiedeman and Klemmedson 1977); this pattern is associated with improved soil conditions. In the case of mesquite, these positive effects may be caused in part by the N fixing ability of the plant, though this has not yet been established. Increased growth of herbaceous plants has also been observed in association with the non-leguminous shrubs, rubber rabbitbush (Frischknecht 1963) and four-winged saltbush (Johnson et al. 1983).

Research is underway to characterize the nitrogen regimes of mesquite and juniper in relation to environmental factors and nitrogen fixation characteristics. Nodulation has occurred in the greenhouse on mesquite roots growing in soil collected from several areas. Nitrogen in the leaf tissue of mesquite collected in several areas is higher than in leaves of other shrub species growing nearby. Also, ratios of ^{15}N to ^{14}N in some locations indicate that mesquite is fixing atmospheric nitrogen. Nodules have been found on roots of established mesquite trees growing in a variety of conditions in the Temple area.

Ratios of the isotopes of oxygen and hydrogen in water appear to vary with depth in the soil. These ratios allow us to determine from where in the soil profile plants are extracting water. Differences in these relationships may reflect levels of water use efficiency, competition for water, and species tolerance to drought stress. High plant water capacitance appears to prolong periods of gas exchange in prickly pear. Water use efficiency is increased by carbon conservation processes, not only by the recycling of respiratory CO_2 but also by sequestering carbon as oxalates, mostly in the form of calcium salt. Findings on gas-exchange

and water-use efficiencies of prickly pear are being extended to test whether water capacitance is related to the ability of mesquite and juniper to compete with herbaceous vegetation in using soil water.

Carbon dioxide response curves for different plant species are being prepared to test the hypothesis that increasing atmospheric CO₂ concentrations favor C-3 woody plants more than herbaceous plants, particularly C-4 grasses. These relationships may partially account for the increase in shrubs over the past several decades and should have important implications in projecting expectations for future vegetation change.

These ecological studies will provide a basis for understanding the interrelationships between invading shrubs and desirable forage plants and how the rangeland ecosystem can be managed for increased efficiency for the multi-use needs of the future.

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Resumen.--Varias especies boscosas y hierbas son malezas en pastizales del suroeste Estados Unidos y norte México. Control biológico por la introducción de organismos (especialmente insectos) de otras áreas del mundo (especialmente Argentina) es una metodología posible para controlar especies nativas como Gutierrezia, Baccharis, Flourensia, Larrea, Prosopis, Hymenoxys, Aloysia, Astragalus, Drymaria, Juniperus, Acacia, y especies introducidas de Tamarix y Salsola. De estas especies, objetos para control son seleccionados considerando la cantidad de daño, valores beneficios y ecológicos, y el potencial de éxito. Malezas que presentemente parecen aceptable a los Estados Unidos y México son Gutierrezia, Baccharis, Flourensia, Hymenoxys y Drymaria; especies adicionales pueden ser consideradas si los conflictos de interés fueran resueltos. Estudios en USA están determinando la ecología de la invasión de arbustos en pastizales, particularmente por Prosopis, Juniperus, y Opuntia. Información de México se requerirá sobre los valores de daño y beneficios de cada hierba para que decisiones se puedan hacer en el mejor interés de los dos países.

Utilización y Comercialización de la Cera de Candelilla¹

Refugio A. del Campo Pérez²

Resumen.--La cera de candelilla se extrae de la planta del mismo nombre (*Euphorbia Antisyphilitica*) y sus propiedades hacen que se le emplee en una diversidad de productos que van desde chicles hasta grasas y tintes. La comercialización cubre el mercado nacional y una buena parte del internacional.

INTRODUCCION

La cera de candelilla es un producto que se extrae de la hierba de candelilla y que compite en importancia con el ixtle de lechuguilla y palma. Pues estos productos, además de significar una alternativa económica complementaria para el ingreso de los campesinos de la región, es también un renglón significativo de ingreso de divisas al país, ya que el mercado internacional de la cera representa un 40% de la demanda total, aproximadamente.

La bondad de la candelilla reside en que es un producto que crece y se reproduce sin ningún cuidado, pues es una planta que prolifera en las regiones mas secas del país y, cuanto mas severas son las condiciones climáticas y mas pobre es el suelo, mas y mejor es la cera que segrega (García Cruz, 1939).

Esta hierba se encuentra con profusión en las regiones mas agrestes del Arido Mexicano, en las laderas de cerros y montes, ensuelos calizos y arenosos, bien drenados. Su poca sensibilidad a plagas y enfermedades hace que se le aproveche, muy frecuentemente, como forraje para cabras y conejos, por lo que es común que su explotación se encuentre asociada a actividades de ganadería menor.

La hierba de candelilla con mayor potencial cerífero crece casi exclusivamente en el desierto mexicano y, en este, preferentemente en la parte mas septentrional pues la hierba que se encuentra hacia el sur, especialmente hacia las costas, tiene un contenido de cera tan reducido que hace incosteable su explotación porque el contenido de resinas supera al de cera y esto la coloca en condiciones de inferioridad respecto a los requerimientos industriales mas usuales. Los principales estados productores de cera son Coahuila, Chihuahua, Durango, Zacatecas y Nuevo León.

¹ Ponencia presentada en la Reunión Sobre Manejo de Plantas en Zonas Áridas. Saltillo, Coahuila, México. Febrero 18-22, 1985.

² Ingeniero Agrónomo. Gerente de Comercialización de los Fideicomisos Relacionados con la Explotación de la Hierba de Candelilla.

Aunque se han hecho intentos de trasplantar la candelilla a países como Haití, Cuba y la República Dominicana los resultados han sido, invariablemente, infructuosos (NAS, 1975).

La reproducción de la candelilla, para efectos de reforestación, se lleva a cabo principalmente mediante trasplantes de tallo y raíz ya que la reproducción por semilla no es viable económicamente por el escaso volumen de simiente que produce la planta y la dificultad para recolectarla (García Cruz, 1939).

Su rendimiento de cera es de un 2 a 2.5% del peso de la planta aunque en el laboratorio es posible duplicar el porcentaje usando disolventes (NAS, 1975), lo que quiere decir que con el procedimiento usual solo se extrae el 50%, aproximadamente, del contenido total de cera de la planta y el otro 50% queda entre los residuos y el bagazo.

Alrededor de la cera de candelilla se han formado una serie de instituciones que van desde el propio grupo de campesinos llamados candelilleros hasta la Asociación Nacional de Productores de Cera de Candelilla y los Fideicomisos relacionados con la explotación del producto.

Las actividades de recolección de la hierba y extracción del cerote, como se llama al producto antes de su refinación, son complementarias de las actividades agrícolas tradicionales del campesino candelillero y el ingreso que este percibe por la venta de su producto le permite complementar su percepción y cubrir los gastos de extracción.

USOS

Los usos y aplicaciones actuales de la cera de candelilla son mucho mas variados de los que tuvo en los primeros años de su acceso al mercado, como era la fabricación de mezclas para velas y productos pulidores y abrillantadores para cuero. La diversificación de las manufacturas en general ha planteado nuevas posibilidades para la cera de candelilla y hoy es posible encontrar que su ámbito abarca campos de producción tan diversos como la fabricación de cosméticos, la industria alimentaria y el moldeo de precisión en la industria aeronáutica.

Con el afán de ilustrar un poco y sin pretender ser exhaustivo, citaré algunos de los usos específicos mas frecuentes y conocidos que tiene la cera en nuestros días ya sea sola o en combinación con otros productos que le agregan nuevas características:

- Como recubrimiento aislante en cables eléctricos y partes en la industria electrónica.
- Como protección de filos y puntas de herramientas para evitar el deterioro durante su transporte y almacenaje.
- Como plastificante en la producción de hules y plásticos para usos múltiples.
- Como componente en la fabricación de barnices, lacas, tintes, grasas, etc. Ejemplo: 'El Oso', 'Amberes', 'Flexo',
- Como agente endurecedor en la fabricación de otras ceras y productos sintéticos.
- Como recubrimiento protector de frutas y en la fabricación de chocolates, chicles y gomas de mascar. Ejemplo: 'Adam's' 'Canel's', 'Omega', 'Totito'.
- Como componente de productos para el acabado fino de cuero y papel.
- Como componente en la fabricación de cintas para máquina de escribir, papel pasante, estenciles. Ejemplo: 'Kores'.
- Como ingrediente en la fabricación de cremas, lápices labiales y otros productos en la industria cosmética. Ejemplo: 'Avon'.
- Como componente de productos para el pulido y abrillantado de madera, pisos y cerámica. Ejemplo: 'Stanhome'.
- Como ingrediente básico en productos para moldeo de precisión en las industrias de relojería, aeronáutica y en la mecánica dental.

Como puede verse, la penetración del producto en el mercado es amplia y actualmente buscamos que sea más profunda pues no se considera que las posibilidades de nuestro producto hayan sido ya agotadas sino que, por el contrario, la constante diversificación de la producción de todo tipo de artículos en que se requieren ceras, abre constantemente una gama potencial de nuevos mercados que debemos atacar.

COMERCIALIZACION

El mercado de la cera de candelilla puede dividirse practicamente en dos, cada uno de ellos con características y comportamientos propios aunque por lo general coinciden en los usos y aplicaciones del producto.

El mercado nacional es mas estable y está menos expuesto a fluctuaciones debido a la protección que el estado brinda a los productores de cera y que consiste, entre otras cosas, en condicionar la importacion de sustitutos industriales de la cera de candelilla, condicionandola al consumo de determinados volúmenes de esta, dependiendo de la rama o giro industrial de los fabricantes. A manera de ejemplo podemos citar a los productores de ceras, grasas y tintes que deben consumir 4 kg de cera de candelilla por cada kilogramo de carnauba que importen, o los fabricantes de papel carbón, cintas para máquina y estenciles, que deben consumir un kilogramo de cera de candelilla por cada 2.5 kilogramos de carnauba.

Si a lo anterior se auna la existencia de un precio oficial del producto se verá que el mercado nacional está, en mucho, controlado sin embargo, la situación dista mucho de ser ideal pues existen algunas áreas del mercado que deben superarse. Quizá la mas frecuentemente mencionada es la de que la cera de candelilla, en su forma actual, por ser un producto de origen natural, tiene algunas fluctuaciones en sus características fisico-químicas que, aunque pequeñas, representan una desventaja frente a las ceras sintéticas y parafinas, de origen mineral, en los casos en que se requiere su participación en formulas de mucha precisión, como es la fabricación de alimentos y cosméticos. Afortunadamente ese segmento del mercado en el que no hemos podido penetrar completamente solo representa un 23% aproximadamente, de la demanda total (ver figura página siguiente).

El mercado internacional presenta mayores fluctuaciones que actualmente se está buscando corregir para llegar mas directamente a los consumidores de cera pues consideramos que la demanda de nuestro producto es constante y va en aumento y que sus fluctuaciones son inducidas artificialmente por los especuladores para obtener mayores beneficios. La base de esta consideración es el hecho de que se cuenta con un 'stock' suficiente del producto para no quedar expuestos a la oscilación en los volúmenes de materia prima, ademas de que el precio al exterior se mantiene constante desde hace tiempo.

Aunque debemos reconocer que nuestro sistema de comercialización aún debe superarse hay que recordar que la comercialización por parte del Fideicomiso de la Hierba de Candelilla se comenzó con 150 toneladas en los inicios de los años sesentas y con una estructura de producción y refinación rudimentaria y que en la actualidad las ventas superan las 1,200 toneladas anuales ademas de que se tiene una estructura de recopilación, refinación y distribución mucho mas estable.

Es necesario insistir en que las ceras naturales, lejos de estar siendo desplazadas por las sintéticas y las de origen mineral -grasas y parafinas- son un complemento indispensable para su fabricación pues a partir de las ceras de origen vegetal se obtienen los componentes para sintetizar y mejorar los productos cada vez mas

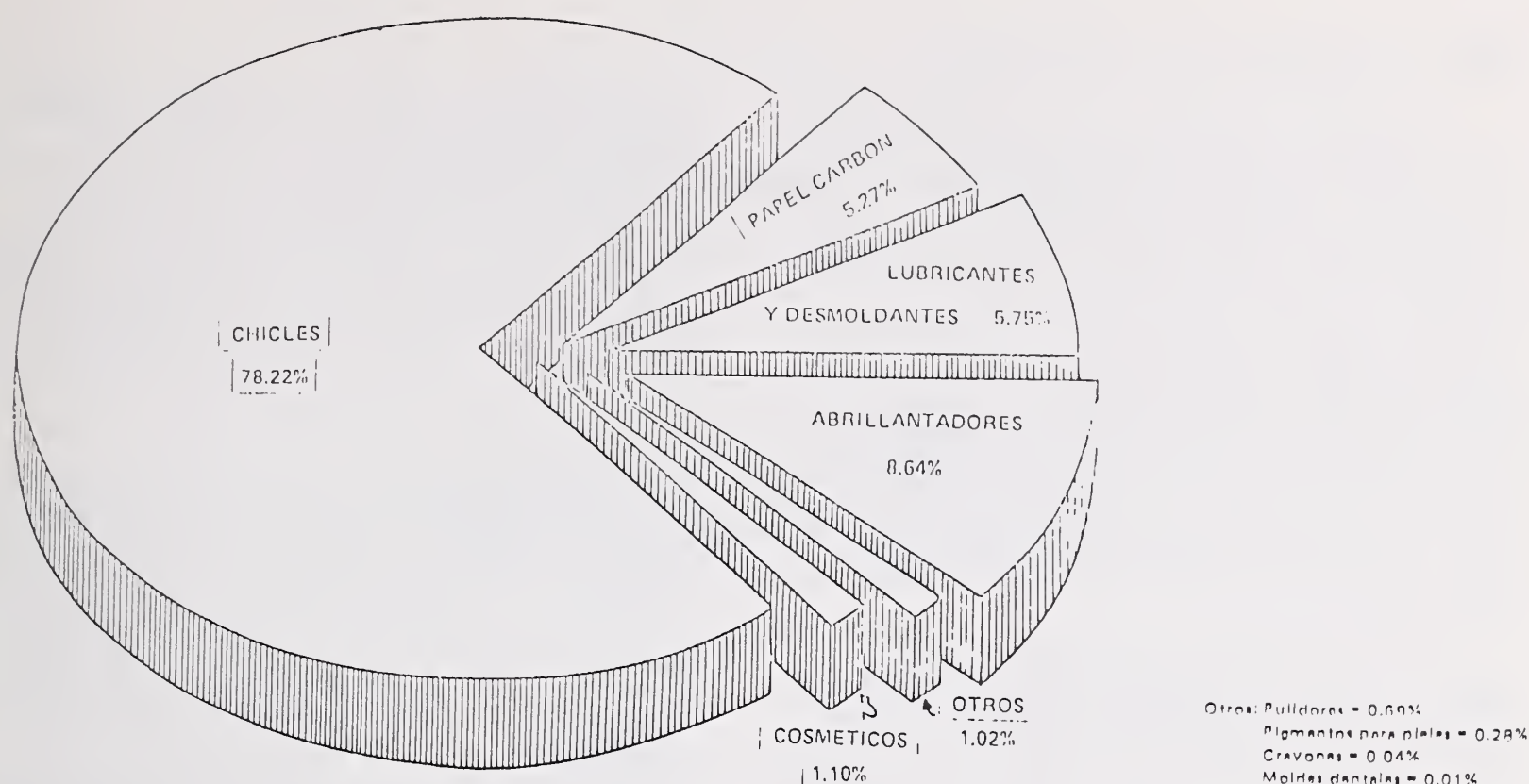


Figura Sectores de consumo de cera de candelilla en el mercado nacional.

diversos y complejos que requiere la industria moderna.

La solución a buena parte de los planteamientos que se han hecho antes respecto a una mas intensiva penetración de la cera de candelilla en el mercado estriba, fundamentalmente, en la diversificación del producto para satisfacer y captar a consumidores con requerimientos especiales y en llevar, mas directamente, el producto a países y regiones donde aún no se haya penetrado, pues aunque la cera se distribuye en la mayoría de los países de Europa Occidental -España, Francia, Italia, Alemania, Bélgica- de los Estados Unidos y Canada y de América Latina -Argentina, El Salvador, Guatemala- y aún en algunos países orientales como Japón y Turquía, consideramos que aún hay mucho mercado por ganar y actualmente se afinan relaciones comerciales para la colocación de nuestro producto en países como la India y otros del Medio Oriente así como con Grecia y otros países de Europa Oriental.

Lo anterior va, necesariamente, de la mano de los correspondientes estudios de ampliación y reestructuración de sistemas y canales de comercialización ya que la perspectiva de un mercado en expansión, de la magnitud que se pretende, presenta un horizonte quizá demasiado amplio.

INVESTIGACION

La investigación en torno a la cera de candelilla, que se considera una necesidad

impostergable, podría agruparse en dos grandes apartados con puntos de vista diametralmente opuestos en apariencia, pero que en realidad son complementarios por una parte la investigación que se ha hecho y se hace actualmente con un enfoque científico, de laboratorio, y por la otra la investigación que se enfoca mas hacia los aspectos técnicos y operativos que si se ha hecho en algunos casos, no ha resuelto todos los problemas que se tienen.

La investigación de gabinete y laboratorio busca la determinación de características y propiedades de la cera y de procedimientos alternativos de extracción para reducir el desperdicio durante el proceso y se buscan, también, nuevas aplicaciones del producto adicionándole tal o cual componente para darle nuevas propiedades pero hasta hace poco no era mucho lo que se había hecho para abordar sistemáticamente la diversificación del producto y la consolidación y ampliación del mercado.

La prioridad, desde nuestro punto de vista y teniendo en mente los intereses de los productores candelilleros, es el estudio del mercado, que es algo en lo que ya se está trabajando, al mismo tiempo que se busca aumentar la producción, pues este otro aspecto de las investigaciones nos interesa, de manera muy particular, cuando de refiere a procedimientos que permitan aumentar la eficiencia de los procesos actuales abatiendo costos, aumentando rendimientos por kilogramo de hierba y suavizando las condiciones de recopilación y extracción para el compesino, pues todo esto nos permitiría sostener nuestros precios por mas

tiempo en el mercado y nos daría mucha mas competitividad frente a otros productos.

Nuestra idea del proceso de comercialización es que este parte del momento mismo de la recolección de la hierba, pasando por el proceso de extracción del cerote y su refinación y, eventualmente, la producción de productos diversos, su presentación y empaque hasta llegar al consumidor satisfecho de nuestro producto. La cadena es compleja y si no se tiene cuidado, se corre el riesgo de tropezar, por eso estimamos indispensable un conocimiento lo mas minucioso y detallado posible del mercado para establecer un flujo constante de nosotros hasta nuestros consumidores. En la medida en que logremos un flujo expedito podremos aumentar nuestra penetración en el mercado y pasar de la estructura de producción actual a una que sea mucho mas eficiente, para lo cual se requerirían estudios e investigaciones adicionales.

Con la interción de ser breves podríamos resumir la investigación que se requiere sobre la hierba y la cera de candelilla a partir de los siguientes enfoques.

Agronómico

Lo mas importante de este enfoque sería continuar con los estudios de adaptación y domesticación del cultivo pues solo con ello se lograría aprovechar al máximo el potencial integral de la planta. A esto deberían agregarse estudios de mejoramiento genético para aumentar la secreción de cera y disminuir el de algunos componentes no deseados creando variedades mas adecuadas a las necesidades del mercado. El mejoramiento de las técnicas de cultivo y de manejo en general. La asociación de cultivos es un aspecto importante con miras a la conservación no solo de este recurso natural sino de otros con los que se presenta en su habitat natural. Los estudios para la reforestación y rescate de zonas devastadas y otros tendientes a la mas regional explotación de la hierba.

Técnico-Industrial

A partir de este enfoque la investigación se centraría en el proceso de extracción, refinación y diversificación de la cera de candelilla y el aprovechamiento óptimo de los subproductos y residuos de la producción de cera en sus diversas fases, tanto en el campo como en la planta.

Económico

Aquí cabrían las investigaciones referentes a los aspectos de mercado, incluyendo transporte y almacenaje así como la asociación de las actividades de recolección y extracción de cerote con algunas otras actividades productivas que conforman el sistema integral de producción campesino con el propósito de aumentar la eficiencia y productividad del trabajo del candelillero así como la de los demas factores que incurren en el proceso desde las etapas iniciales hasta las finales.

Sociales

Finalmente, aunque no en último lugar, es necesario realizar investigaciones continuas para el mejoramiento de las condiciones generales y la calidad de vida de los asentamientos humanos donde se produce la candelilla, con la finalidad de planificar apropiadamente las obras e inversiones de beneficio social que son el propósito de una de las instituciones candelilleras de que hablabamos al principil; el Fideicomiso para la Hierba de candelilla.

El panorama general que, por necesidades de sistema y claridad, se presenta aquí separado partiendo de varios enfoques, en la práctica deberá conformar una visión completa della región candelillera con un eslabonamiento y una interdependencia estrecha entre los estudios que se realicen para que sean unos el complemento y fundamento de los otros y se optimicen tanto los resultados que se obtengan, como los recursos que a ellos se apliquen.

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Summary.--The Candelilla wax is extracted from the plant of the same name (*Euphorbia antisiphilitica*) and because of its properties it is used in a great variety of products, from chewing gums to oils and dyes. The commercialization of this product covers the national market, as well as great part of the international market.

Candelilla: la Necesidad de un Cambio

Obed Chávez Pruneda²

Resumen.--La siguiente ponencia toma los resultados de un estudio desarrollado en 1979 y mediante el cual se lograron identificar diferentes argumentos, la mayoría de ellos aun válidos, que justifican un cambio en todas las etapas del proceso de aprovechamiento de la cera de candelilla.

ANTES DE 1979

Previo a 1979, se habían venido desarrollando una gran cantidad de estudios que sobre diferentes aspectos y en diferentes partes del mundo tuvieron como parte central a la candelilla (cuadro 1).

El desfase en el tiempo y en el espacio de todos estos estudios, les hizo ser aislados, y por lo mismo en la gran mayoría de ellos las aportaciones importantes que sus resultados pudieron hacer al mejoramiento del sistema comercial en operación fueron muy pocas. Por otro lado, el sistema comercial de la candelilla durante este tiempo se mantuvo ajeno a un buen número de tales resultados. Además, muchos aspectos que requirieron y aun requieren de consideración, no hubo quien los atendiera.

De una manera u otra, faltó una visión de todo el sistema comercial, con la intención de que conociéndolo en su totalidad, pudieran plantearse opciones que permitieran mejorar sensiblemente su funcionamiento.

1979

Así, con algunos antecedentes en torno a la candelilla, y con la preocupación tanto de la ineficiencia del proceso de extracción de la cera como de la posible erradicación del recurso, el CIQA con el apoyo de BANRURAL (ahora FONCAN) y CONAZA, se echa a cuestras la tarea de evaluar las posibilidades de innovar el proceso global de aprovechamiento de la candelilla.

Para tal propósito, se integra un equipo de investigadores de diferentes especialidades y pertenecientes a las tres instituciones mencionadas.

¹ Ponencia presentada en la Reunión Sobre Manejo de Plantas en Zonas Áridas. Saltillo, Coahuila, México. Febrero 18-22, 1985.

² Ingeniero Químico, Jefe del Área de Estudios y Proyectos Especiales, - CIQA, Saltillo, Coah.

Mediante el estudio se integró la información ya existente en un formato que permitiera la comparación entre los dos sistemas de aprovechamiento de la candelilla: Actual (H_2SO_4) y Propuesto (Solvente). De esto se derivó la estructuración de un archivo de artículos, patentes, tesis y libros que actualmente se encuentra en la biblioteca del CIQA. La información faltante, se generó con trabajo de campo.

Algunos de los aspectos relevantes que se detectaron en el desarrollo del estudio son los siguientes:

"El aprovechamiento comercial de la candelilla se remonta a principios de siglo; la extracción de la cera con el método que actualmente se usa (ácido sulfúrico H_2SO_4) data de 1912."

La actividad candelillera involucra alrededor de 3500 productores, teniendo un registro al régimen del IMSS de 20,000 personas.

El sistema de producción actual de la cera de candelilla, requiere en mano de obra, 2087 hr-h/ton de cera producida. Esto significa que, considerando semanas de 40 horas, se requiere del trabajo de una persona durante 1 año para producir una tonelada de cera.

Por otro lado, el tiempo que se dedica a las diferentes labores del quehacer candelillero, se distribuye según se muestra en el cuadro 2.

Podrá observarse que una buena parte (33%), es tiempo improductivo que además mantiene dispersos a los candelilleros y cada vez más alejados de sus lugares de origen.

Pudimos observar, que la producción presenta una distribución muy heterogénea, pues si por un lado hay quienes producen de 2-3 veces su cuota (27% de los ejidos), hay quienes ni siquiera cumplen con el 20% de la misma (10% de los ejidos). Como resultado de esto, se observó que solo el 15% de los ejidos (34) son responsables del 42% de la producción.

Cuadro 1. Lista de los estudios más importantes que sobre candelilla se realizaron hasta antes de 1979.

Tipo de estudio	Nivel	Año	Institución que realizó el estudio	País
Análisis de la cera	3	1907	Instituto Médico Nacional	México
Análisis de la cera	3	1910	Texas Agricultural Experiment Station	U.S.A.
Análisis de la cera	3	1925	Laboratoire Municipal de París	Francia
Blanqueo y refinación de la cera	3-4	1936	Institut für Chemische Technologie II der Deutschen Technischen Hochschule	Alemania
Recopilación de información	1-5	1939		México
Propagación de la Candelilla	1	1942	Escuela Nacional de Agricultura	México
Estudio sobre la actividad proteolítica del látex de la Candelilla	3	1942	Escuela Nacional de Ciencias Biológicas, I.P.N.	México
Estudio botánico de la Candelilla	1	1944	Instituto de Biología, U.N.A.M.	México
Método para determinar el número de saponificación de ceras	3	1949		Alemania
Método para determinar el número de saponificación de ceras	3	1949	Laboratoire des Corps Grass du C.N.R.S.	Francia
Análisis de la cera	3	1949	University of Wisconsin	U.S.A.
Efecto de la composición sobre la gravedad específica en mezclas de ceras	5	1950		U.S.A.
Uso de la cera en compuestos para pulir	5	1952		U.S.A.
Estudio de la extracción y refinación de la cera	4	1952	Instituto Mexicano de Investigaciones Tecnológicas	México
Estudio de la extracción de la cera y obtención de pulpa celulósica de Candelilla	4-5	1953	Instituto Mexicano de Investigaciones Tecnológicas	México
Estudio de la extracción y refinación de la cera y obtención de pulpa de la Candelilla	4-5	1953	Instituto Mexicano de Investigaciones Tecnológicas	México
Estudios de la refinación de la cera	4	1953	Southwest Research Institute	U.S.A.
Recopilación de información	1-5	1953	Engineering Experiment Station of Georgia, Institute of Technology	U.S.A.
Recopilación de información (tesis)	1-5	1954	Escuela Superior de Agricultura Antonio Narro	México
Recopilación de información	1-5	1954		U.S.A.
Análisis de suelos candelilleros y contenido de cera en la Candelilla (tesis)	1	1954	Escuela Superior de Agricultura Antonio Narro	México
Recopilación de información	1-5	1955		U.S.A.
Estudios del índice de refracción de mezclas de ceras	3-5	1955	Ursuline College-Louisville, Kentucky	U.S.A.
Determinación de hidrocarburos en cold cream	5	1956	Food and Drug Administration	U.S.A.
Estudios de las propiedades impermeabilizantes de la cera	5	1956		Francia
Análisis de la cera	3	1957		Alemania
Estudio histoquímico y determinaciones en el extracto céreo de la Candelilla (tesis)	1	1957	Escuela Nacional de Ciencias Químicas, U.N.A.M.	México
Contribución al estudio de la Candelilla	1-5	1958	Escuela Superior de Agricultura Antonio Narro	México
Recopilación de información	1-5	1958	Escuela Nacional de Agricultura	México
Recopilación de información	1-5	1964	Instituto Mexicano de Recursos Renovables, A.C.	México
Propiedades físicas y químicas de ceras vegetales	3	1969		U.S.A.
Identificación de la cera por cromatografía en capa delgada	3	1971	Farbwerke Hoechst AG, Werk Gersthofen	Alemania
Análisis sistemático de la cera	3	1972	Shiseido Laboratory-Kamiya, Kita-Ku	Japón
Recopilación de información (tesis)	1-5	1972	Escuela Nacional de Agricultura	México
Análisis de la cera	3	1973	Instituto Mexicano de Investigaciones Tecnológicas, A.C.	México
Análisis de la cera	3	1973	Prairie Regional Laboratory	Canadá
Uso de la cera en el recubrimiento de frutas	5	1974	Laboratorios Nacionales de Fomento Industrial	México
Aplicación de la cera al recubrimiento de frutas	5	1974	Comisión Nacional de Fruticultura y Facultad de Química, U.N.A.M.	México
Análisis de la cera	3	1974	The University of Michigan	U.S.A.
Análisis de la cera	3	1974	Prairie Regional Laboratory	Canadá
Recopilación de información	3-5	1975		U.S.A.
Análisis de la cera	3	1975	Prairie Regional Laboratory	Canadá
Análisis de la cera por GPC y VPO	3	1975	Centro de Investigación en Química Aplicada	México
Cloración de la cera	5	1975	Centro de Investigación en Química Aplicada	México
Evaluación de la cera clorada como plastificante en PVC	5	1975	Centro de Investigación en Química Aplicada	México
Análisis de la cera	3	1976	Fire Investigación Sec. NIPS	Japón
Análisis de la cera	3	1976	Institut für Organische Chemie and Biochemie, Tschechoslowakische Akademie der Wissenschaften	Checoslovaquia
Diversificación de su uso	3-5	1977		México
Análisis de la cera	3	1977	Laboratories Wolf	Francia
Evaluación cualitativa y utilización de residuos de Candelilla en la alimentación de rumiantes (tesis)	5	1977	Escuela Nacional de Agricultura	México
Estudio socioeconómico de los candelilleros del área periférica de la comarca lagunera	S.E.	1977	Centro de Investigaciones Superiores del INAH	México
Mejoramiento de las propiedades térmicas de la cera	5	1977	Centro de Investigación en Química Aplicada	México
Extracción de la cera con solventes	4	1978	Centro de Investigación en Química Aplicada	México
Análisis de carbohidratos en el bagazo	3	1978	Centro de Investigación en Química Aplicada	México
Estudio descriptivo en cuatro ejidos candelilleros	1 S.E.	1978	Universidad Autónoma Agraria Antonio Narro	México
Recopilación de información	1 S.E.	1979	Universidad Autónoma Agraria Antonio Narro	México

Claves de los niveles

1 La planta. 2 Abastecimiento 3 Propiedades y composición química 4 Transformación.
5 Distribución, usos, subproductos. S.E. Estudio socioeconómico.

Cuadro 2. Composición del tiempo consumido en la obtención de 1 ton de cera.

Actividad	%
Traslado y transporte de la hierba	33
Recolección y empaque del arbusto	36
Extracción del cerote	30
Refinación	1

Un aspecto que no ha recibido la atención que merece, es lo relacionado al inventario del recurso, pues el único estudio que se conoce que tuvo este objetivo se desarrolló en 1965 y la única información que generó en torno a la candelilla fue:

Area ocupada = 85,580 km²

Area explotada = 47,025 km²

En cuanto al mercado de la cera pudimos identificar sus usos, productos competitivos, países consumidores, propiedades y establecer estadísticas en relación con su demanda, producción, exportaciones y precios.

Con relación a lo ambiental, pudimos observar que por cada tonelada de cera que se produce actualmente, se descartan al ambiente 0.5 ton de ácido sulfúrico. Además no hay ninguna acción tendiente a preservar el recurso, dadas las actuales prácticas de recolección del arbusto y a la ausencia total de algún sistema que asegure su recuperación.

Del análisis efectuado en el estudio, se derivaron resultados tales como los siguientes:

Con base a los municipios reportados como candelilleros a la fecha del estudio, pudimos estimar la superficie de la región candelillera, misma que resultó ser de 172,064 km²; la división de esta región, atendiendo al criterio de contribución a la producción, dio como resultado: 2 zonas de 1000 ton/año cada una, 1 de 500 ton/año y 1 de 200 ton/año.

Los resultados obtenidos en el análisis financiero de las diferentes opciones propuestas se muestran en el cuadro 3.

Cabe hacer énfasis en que un análisis de los componentes del costo de producción en el sistema con solventes intermitente, revela que el 46% se debe al costo de la candelilla, por lo que resulta obvia la necesidad de minimizar en lo posible este concepto.

Cuadro 3. Resumen de los resultados de la evaluación financiera de las opciones propuestas.

Concepto	Sistema		
	Actual (H ₂ SO ₄)	Propuestos Intermitente	Continuo
Costo de producción, \$/kg	37	26 (70%)*	23 (62%)*
Precio de venta, \$/kg	40	35	35
Inversiones, millones de pesos	-	34	39
Punto de equilibrio, %	-	50	37
Tasa interna de retorno, %	-	15	20
Recuperación de inversión, años	-	5.5	4.5

* Porcentaje con respecto a costo del proceso actual

Una comparación entre las necesidades de los dos sistemas (actual y propuesto) permite destacar los siguientes puntos:

- *La superficie requerida en abastecimiento para el sistema propuesto es aproximadamente 1/3 de la que se dedica en el sistema actual
- *Los requerimientos de energía en la transformación del sistema propuesto son del orden de 1/5 de los del actual
- *La eficiencia de extracción de la cera en el sistema propuesto es prácticamente el doble de la del actual.
- *En términos de mano de obra, el proceso propuesto requiere en total, solo el 55% del tiempo del actual. En la fase de abastecimiento el sistema propuesto solo requiere un 66% de las necesidades del actual, mientras que en transformación el porcentaje es de 30% (cuadro 4)
- *En lo que se refiere a calidad, aparentemente el tratamiento con ácido sulfúrico es tan severo, que se cree que modifica la estructura química original de la cera, en detrimento de sus propiedades finales.

Finalmente, el análisis realizado se integró en la presentación de un proyecto, en el que el propósito fundamental era substituir gradualmente el sistema actual de aprovechamiento de la candelilla por otro más racional y eficiente; se elaboraron el calendario de actividades y los presupuestos correspondientes.

Los aspectos más importantes que en este proyecto se planteaba cubrir son:

- Abastecimiento
 - .Inventario
 - .Estudio ecológico
 - .Reforestación
 - .Cultivo
- Transformación
 - .Estudios piloto del proceso de extracción con solventes
 - .Opciones de utilización del bagazo
 - .Ingeniería básica
 - .Estudio de preinversión
 - .Ingeniería de detalle
 - .Construcción de una planta de 1000 ton/año
 - .Construcción de 5 plantas intermitentes (1000 ton/año cada una)
 - .Proceso continuo
- Distribución
 - .Estudio de mercado
- Estudios especiales
 - .Estudio socioeconómico
 - .Transferencia tecnológica

DESPUES DE 1979

El planteamiento del proyecto no logró la aceptación y el apoyo que se esperaba, particularmente en las instituciones adecuadas para tal fin. Sin embargo, con los pocos recursos que se pudo contar, el CIQA apoyado por CONAZA logró sacar algunos de los aspectos planteados en el proyecto:

Cuadro 4. Requerimientos de mano de obra, expresados en - hr-h/ton de cera.

Actividad	Proceso actual H ₂ SO ₄	Proceso propuesto Solvente
Abastecimiento	1447	952 (66%) #
. Recolección y empa-	762	300 (39%) #
cado		
. Transporte	685	373 (54%) #
. Reforestación	-	244
. Desmonte	-	35
Transformación	640	192 (30%) #
. Extracción	624	192
. Refinación	16	-
Total	2087	1144 (55%) #

Porcentaje de requerimientos con respecto a los del proceso actual

* En lo que se refiere a calidad, aparentemente el tratamiento con ácido sulfúrico es tan severo, que se cree que modifica la estructura química original de la cera, en detrimento de sus propiedades finales"

- .Estudios piloto del proceso de extracción con solventes
- .Sondeo de posibles opciones de utilización del bagazo
- .Elaboración de la ingeniería básica del proceso de extracción con solventes
- .Estudio de localización para una planta de 1600/año
- .Estudio de mercado nacional para la cera de candelilla

El proyecto como tal, continúa débil en muchos aspectos: En cuanto al recurso poco sabemos; del mercado, lo mismo (sobre todo con lo cambiante que es) y en cuanto a la idea de integrar todo resultado dentro de un marco con gruencia de objetivo común (proyecto), estamos como al principio.

Si en algo podemos decir que hemos avanzado, es en el conocimiento del proceso de obtención de cera usando solventes, pero aun ahí, todavía tenemos carencias.

Es evidente pues, la necesidad de un cambio; es posible llevarlo a cabo, pero para empezar, este cambio debe llevar como uno de sus componentes y quizá el más importante, el cambio en actitudes.

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Summary.--This work has taken the results of a study developed in 1979, in which it was possible to make different statements, most of them currently strong, that justify a change in all stages of the Candelilla wax exploitation process.

245 Yerba del Manso: An Evaluation¹

Margaret Caffey-Moquin²

Abstract.--Anemopsis californica (Saururaceae) is a rhizomatous plant native to moist, low-elevation habitats within the arid regions of the southwestern United States and northern Mexico. Throughout its geographic range, the plant holds an important place in traditional folk medicine, especially as a vulnerary. It has also been reported as a stomachic, a cardiovascular tonic, a diuretic, and cough suppressant. Published ethnobotanical and phytochemical observations on Anemopsis are combined with preliminary results of new investigations for an evaluation of the plant's potential as a source of useful medicines.

INTRODUCTION

"Yerba del manso" is a colloquial name used in New Mexico for Anemopsis californica (Nutt.) Hook. and Arn. (Fam. Saururaceae). In other parts of the southwestern United States, particularly California, the similar name "yerba mansa" appears to prevail (Curtin 1947). In Mexico, the plant may be known as "bavisa" (Ford 1975). Most Indian languages that have developed within the plant's geographic range contain one or more appellations that often relate to specific medicinal applications. Because the genus Anemopsis is monospecific, the generic epithet will be used below.

Two morphologically distinguishable varieties of A. californica have been described by Kelso (1932) and were considered by him to occupy more or less disparate parts of the overall geographic range of the species (see fig. 1). An unexpected occurrence of var. californica within the area typically occupied by var. glabra (Caffey-Moquin 1984) may provide supporting evidence for the hypothesis that the present-day distribution of Anemopsis has resulted from anthropochory. The fact that Anemopsis is restricted to hydric habitats--more or less isolated oases surrounded by desert--may serve to

further corroborate this view. It may now be apparent to the reader that Anemopsis is hardly a xerophyte; it is, however, limited to the desert biome (sensu latu) of North America, and its continued ethnomedicinal importance is evident in the ubiquity of its folk-usage among the human inhabitants of those arid lands.

Nearly all of the early ethnobiologists working in the Greater Southwest (northwestern Mexico and the southwestern United States) included Anemopsis in their lists of plants useful to the peoples with whom they had made contact. Dried Anemopsis rhizomes are almost always featured among medicinal herbs offered for sale at open-air markets in New Mexico. They are also standard at regional fairs such as that of San Francisco at Magdalena de Kino, Sonora (Nabhan 1982). There are several major categories of disease that traditionally have been treated with Anemopsis. In the ethnobotanical literature, the most consistent application of Anemopsis appears to be as a vulnerary poultice, whether the leaves or rhizomes are employed.

Somewhat less prevalent in the literature, yet stressed in personal interviews conducted in New Mexico, is the plant's reputed value as a stomachic for both ulcers and dysentery. In this context, a decoction is typically prepared from the roots and rhizomes and drunk at frequent intervals.

Anemopsis rhizomes may also be employed in "blood purification" (Moore 1977), an ambiguous term which may imply a cardiostimulant effect. Gogel (personal communication) has related that a routine radioimmunoassay of the blood of a cardiac patient who frequently ingested Anemopsis tea while simultaneously receiving prescribed digoxin therapy revealed unexpectedly elevated blood levels of digoxin-type antigens. This suggests that Anemopsis may contain substances,

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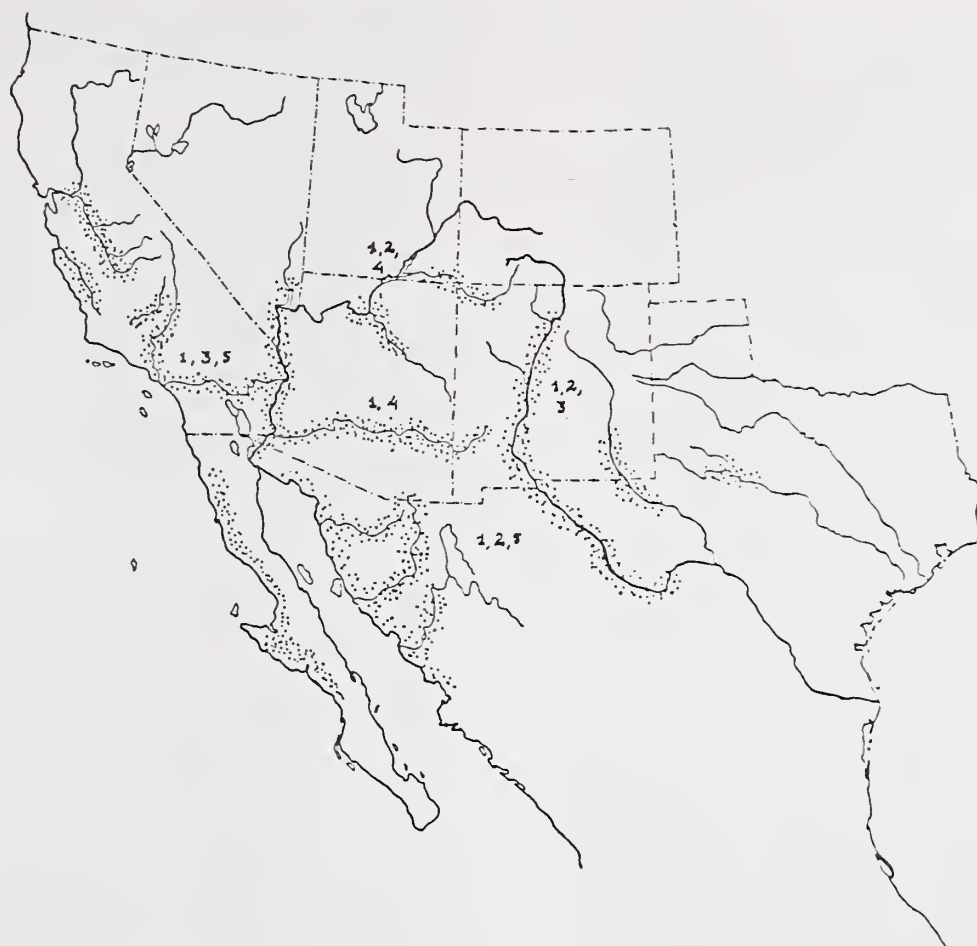


Figure 1.--Potential geographic distribution of *Anemopsis californica*. Numerals encode localities of reported ethnomedical uses as follows: (1) vulnerary; (2) stomachic; (3) cardiovascular tonic; (4) diuretic; (5) cough suppressant.

presumably cardioactive, whose radioimmunoassay behavior resembles that of digoxin.

Anemopsis was reported as the major ingredient of at least one diuretic prescription of Eastern Navajo healers interviewed by Wyman and Harris (1947). Its internal use in the treatment of venereal disease (Train et al. 1957, Hrdlička 1908) may relate to diuresis. In the western part of its range, i.e., in California, *Anemopsis* has been used as a cough suppressant (Childs and Cole 1965, Zigmond 1981).

Horton and Paul (1957), Sanvordeker and Chaubal (1969), and Tutupalli et al. (1973) reported, respectively, the isolation of three phenylpropanoids, methyl eugenol, esdragol, and elemicin from essential oil of *Anemopsis*. Methyl eugenol, reported as the major constituent of *Anemopsis* oil by Acharya and Chaubal (1968), is thought to be mutagenic (Ames 1983). On the other hand, it has been tested for antitumor activity (Childs and Cole 1965), with negative results when strict activity criteria were applied. Pronounced antispasmodic activity was exhibited by methyl eugenol in another assay performed by Childs and Cole (1965); however, the authors found a widely available commercial preparation to be far stronger.

Tutupalli and Chaubal (1971), from their analysis of a light-petroleum extract of *Anemopsis*, reported the third isolation of (+)-asarinin from a plant source. The authors did not speculate on the possible medicinal applications of this compound; however, its isomer (-)-asarinin, has apparently been used as an antitubercular agent (Merck 1968). Piperitone and thymol composed varying proportions of *Anemopsis* oil, according to whether fresh or dried plant materials were extracted. Thymol, the second most abundant constituent (Tutupalli et al. 1973) of the "commercial drug" (sic) [probably dried rhizomes] has antifungal properties according to Merck (1968).

SOME PRELIMINARY INVESTIGATIONS

Bioassay

A decoction of *Anemopsis* was obtained by boiling 9.0 g of intact dried rhizome in 250 ml H₂O for 15 minutes. This procedure simulated the usual home preparation method, except that the infusion was triple the normal strength. The extract was passed through a 0.45 µm filter into a sterile flask to avoid the introduction of any undesired microorganisms to the experiment.

Five enteric pathogens were chosen for the assay: Vibrio cholera, the cholera pathogen; Salmonella typhimurium and Shigella flexnerii, two commonly encountered causes of food poisoning; and Enterobacter aerogenes and Escherichia coli, typical components of normal intestinal microflora that may become pathogenic under unusual conditions. Vibrio was cultured in BHI broth and BHI agar (Difco); all others were cultured in nutrient broth and nutrient agar.

Experimental culture tubes contained a mixture of filtered extract and the nutrient medium appropriate to the inoculum. Each organism was inoculated into a five-fold dilution series of extract in culture medium. Normal growth of organisms, as evidenced by visible turbidity, was ascertained by culturing an inoculated tube of pure medium for each organism. Two tubes of pure extract, uninoculated, were incubated along with the others to make certain that the extract itself was sterile.

A parallel test using growth plates was carried out at the same time. Extract was applied dropwise to saturate 0.45 µm filter discs (Millipore) of 1 cm diameter kept in an enclosed sterile dish. Plates containing nutrient medium were inoculated using the streak-plate technique to result in four dilutions of inoculum on each plate. Two replicates were inoculated with each organism. Saturated filter discs were placed onto the junction of the second and third dilution sections of each plate.

The experimental control for each organism in the growth-plate experiment consisted of one plate inoculated with that organism in the manner described above, but with a dry filter disc containing no extract. All plates and tubes were incubated at 37°C for 48 hours before final observation.

No definite inhibition of growth was observed for any of the organisms exposed to Anemopsis extract, whether in tube or plate culture. A slight depression of growth, however, was observed at the highest concentration of extract for tube cultures of Shigella and Salmonella. Because the uninoculated extract controls exhibited no growth, the experimental conditions can be presumed to have been aseptic. Moreover, the organisms in pure culture displayed normal growth, indicating that appropriate growth conditions were maintained.

Cardiac Glycoside Screen

A typical cardiac glycoside consists of an aglycone and its attached deoxy sugar(s). The aglycone comprises a steroidal nucleus and an unsaturated lactone ring. The latter is apparently the principal molecular locus of cardioactivity involving Na⁺-K⁺ exchange (Tyler et al. 1981); however, the steroidal nucleus is an intrinsic part of the aglycone and may play a specific role of its own. Cardioactive aglycones may be either cardenolides or bufadienolides; i.e., they may possess either a butenolide or a

pentadienolide lactone ring, respectively (Sim 1967). Because of its pharmacological importance and ease of detection, the lactone ring is often the first functional group to be screened.

The Kedde test is designed to detect the presence of butenolides, or 4-C unsaturated lactone rings (Sim 1967). The Bush and Taylor modified reagent (Fong et al. n.d.) is prepared by adding 50 ml 5.7% (w/v) KOH to 1.00 g 3-,5-dinitrobenzoic acid dissolved in 50 ml MeOH and is suitable for spraying. An alcohol solution of pure cardenolide is typically colorless and will rapidly change to violet upon treatment. Crude plant extracts containing butenolides may be expected to evince other color changes.

In order to maximize potential retrieval of cardiac glycosides from Anemopsis, a large-volume extract was made. Five hundred grams of dried rhizomes and roots were ground in a Wiley mill fitted with a 1 mm sieve. The powder was extracted with 1000 ml methanol (99%) in a shaker bath (80 oscillations/min) for 1 hour at 37°C. Addition of 500 ml methanol facilitated the recovery of the supernatant, and the remaining slurry was decanted in portions into a mortar. Each portion was crushed to a paste, then filtered. The resulting filtrates were recombined with the original supernatant to yield a total of 800 ml of dark brown extract.

Petroleum ether (120 ml) was combined with the extract in a separatory funnel. The more nonpolar of the two resulting emulsion layers (fraction I) was redissolved in 300 ml petroleum ether, evaporated in vacuo to a syrup (150 ml) and repetitively extracted with water. The residues of each aqueous extraction were named fractions II - IV in order of decreasing polarity.

Crude methanol extracts were obtained by adding 10 ml solvent to 0.5 g ground plant tissue (Anemopsis rhizome or Digitalis leaf). After thorough crushing in a hand-held glass homogenizer, each slurry was filtered. The cardenolide standards were two constituents of Digitalis leaf digitoxin and lanatoside A kindly supplied by Dr. Bliss, College of Pharmacy, University of New Mexico. Approximately 100 mg of each cardenolide was dissolved in separate aliquots (2 ml) of methanol.

Four fractions of the large-volume Anemopsis extract were assayed simultaneously with the preparations just described (see table 1). Pure methanol was used as a control. All samples were applied to Whatman #3 paper with capillary tubes. Each test spot consisted of ten sample aliquots applied serially to the same point, with air-drying between each pair of applications. Kedde reagent was sprayed over the sample array until the paper was thoroughly wetted.

Treatment produced instantly observable changes in the colors of both pure cardenolides and of the crude methanol extracts of both

Table 1.--Kedde Test Results

Species	Source Sample	Color of Sample	
		Before treatment	After treatment
(none)	MeOH	none	no change
<u>Digitalis</u> sp.	crude MeOH extract	grass green	olive green [†]
"	digitoxin in MeOH	none	iris purple [†]
"	lanatoside A in MeOH	none	pale iris [†]
<u>Anemopsis</u> <u>californica</u>	crude MeOH extract	transparent straw	medium brown [†]
"	fraction I (MeOH/p. eth.)	light brown	no change
"	fraction II (MeOH/p. eth.)	brown	no change
"	fraction III (MeOH/p. eth.)	rich brown	no change
"	fraction IV (MeOH/p. eth.)	pale tan	†

[†] Pronounced dark ring surrounded spot after treatment.

Digitalis and Anemopsis. Pure methanol displayed no color change. Fractions I - III of the large-volume extract did not change; in contrast, a ring formed around fraction IV.

DISCUSSION

As noted above, the bioassay demonstrated no inhibition of the organisms cultured with Anemopsis extract. A slight depression of growth was observed at the highest extract concentration in tube cultures of Shigella and Salmonella. The attainment of that concentration, however, required such an adjustment in the amount of available nutrient medium that the observed growth depression may be attributable to a paucity of nutrients rather than to the concentration of extract per se. It can be concluded that, even at triple the typical concentration of Anemopsis decoction, in vitro inhibition of the enteric pathogens tested was not confirmed.

While a myriad of modifying influences may accompany the Anemopsis-pathogen interaction in vivo, and may even tip the balance in favor of inhibition, the results of this experiment cannot be said to support the idea that the usefulness of Anemopsis in the treatment of dysenteries is strongly related to direct antibiotic activity. The widespread use of Anemopsis tea in New Mexico in the relief of chronic, autogenic digestive tract disorders such as ulcers suggests that the beneficial properties, if any, of Anemopsis somehow affect human digestive physiology.

The results of the cardiac glycoside screen, while preliminary, do not weigh strongly in favor of any putative cardioactivity which has been ascribed to Anemopsis. While it is true that a crude MeOH extract of Anemopsis gave an apparent positive Kedde test, the fractions of the large-volume, more concentrated MeOH extract which seemed most likely to contain cardiac glycosides or aglycones gave either equivocal or

negative results in the same test. It is conceivable that butenolide-containing compounds were originally present in the unrefined large-volume MeOH extract and that they were altered during partitioning of that parent extract into the fractions that were assayed. Moreover, because pentadienolides may give negative Kedde tests (Sim 1967), the question of whether Anemopsis contains cardiac glycosides cannot as yet be resolved.

It is clear that much further investigation, especially pharmacological testing, will be necessary before a definitive statement can be made regarding the potential of Anemopsis as a source of useful medicinal substances. On the other hand, although the known constituents are few, they include an array of compounds with possible therapeutic value, adding further interest to this traditional arid-zone "yerba."

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Resumen.--Anemopsis californica (Saururaceae) es una planta rizomatosa nativa en hábitats con húmedad y baja elevaciones entre las zonas aridas del sudoeste Estados Unidos y partes del norte de México. Por toda su rango geográfica, la planta tiene un lugar importante en remedios caseros, especialmente como vulnerarios. Tiene usos como un estomacal, tónico cardiovascular, diurético, y suprimidor de la tos. Aquí, observaciones etnobotánica y fitoquímica sobre Anemopsis son compuestas con resultados preliminaro de investigaciones para la evaluación de potencial de la planta como medicinas útil.

Indian Ricegrass (*Oryzopsis hymenoides*): A Potentially Useful Wild Grass Adapted to Dunal Habitats¹

Anne C. Cully²

Abstract.--Indian ricegrass or *Oryzopsis hymenoides* (Roemer and Schultes) Ricker is a native grass adapted to sandy soils in arid locations. The foliage is high in protein and makes excellent winter forage for livestock. The large, nutritious seeds germinate and grow well in deep sands. There has been a long tradition of use of Indian ricegrass by southwestern Indian people that is documented in the archeological record and in ethnographic data. Indian ricegrass has the potential for providing valuable nutritional supplements for man and forage for grazing animals in areas that would otherwise be non productive.

INTRODUCTION

Indian ricegrass or *Oryzopsis hymenoides* (Roemer and Schultes) Ricker is a densely tufted, perennial bunchgrass that occurs mainly on dry sandy soils throughout western North America in Canada, the United States, and northern Mexico (figure 1). It is closely related to needle grasses (*Stipa*), and often forms sterile hybrids with species of this genus where the ranges overlap. The blades are slender and involute. Indian ricegrass panicles are diffuse and delicate, with spikelets on long, slender pedicels. The seeds (consisting of the caryopsis enclosed by the indurate lemma and palea) are nearly round, black or dark-brown, tipped with a short awn, and are covered with conspicuous white hairs. Indian ricegrass is frequently an important species on sand dune areas, and it reproduces entirely by seed (Hitchcock 1971, Hoover et al. 1948). The large seeds provide energy for seedlings to germinate and reach the surface from under as much as 7 cm of sand (Young et al. 1983). The seeds generally ripen in June or early July, and most of the crop falls from the plants within a two week period. The success of the crop is linked to winter and spring moisture. Good moisture later in the summer can produce a second, smaller crop of seed in September. Although seed viability is high, tested germination rates are low (Charles H. Diebold pers. comm., McDonald and Khan 1977, Rogler 1960). This has been attributed to the indurate lemma and palea surrounding the caryopsis, to embryo dormancy, and to inhibitory substances in the seed coat (McAdoo et al. 1983, McDonald and Kahn 1977, Rogler 1960, Young et al. 1983). The indurate lemma and palea seem to play the primary role in the delay of germination. Germination has been enhanced by

scarification with sulfuric acid, although this was sometimes found to severely damage the seed (McAdoo et al. 1983, Rogler 1960, Toole 1940). In artificial seeding, seeds that are cracked during mechanical harvesting have been observed to germinate well (Robertson 1977).

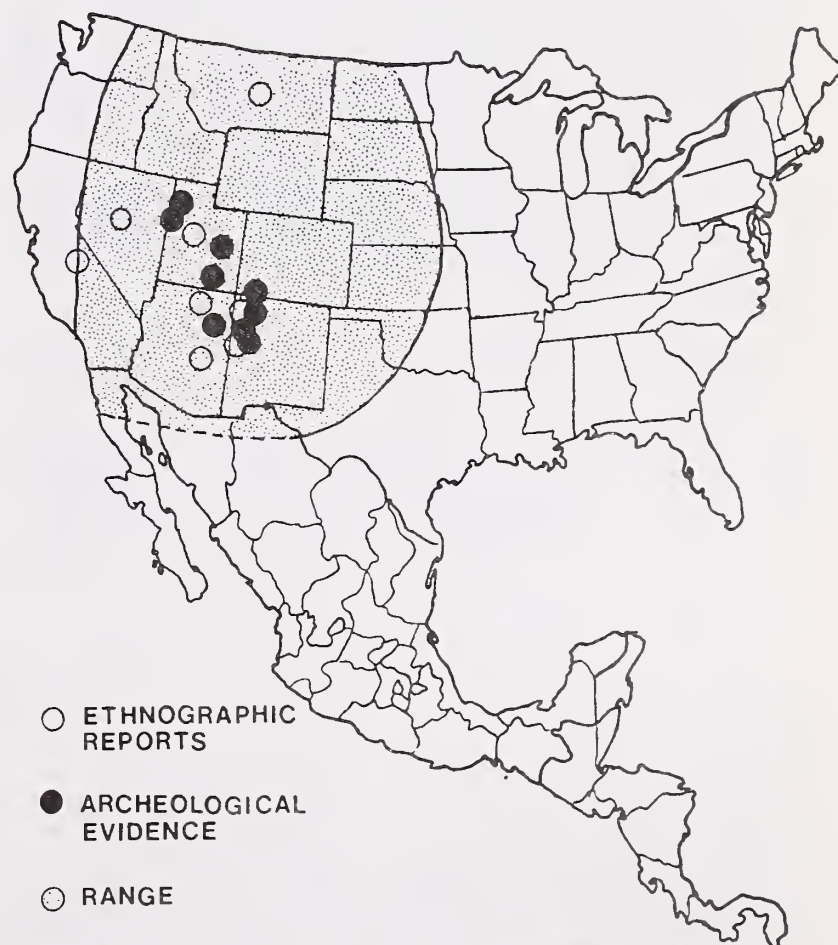


Figure 1. The range of *Oryzopsis hymenoides* in the western United States and Mexico; locations of ethnographic reports and archeological evidence for the use of Indian ricegrass.

¹ Paper presented at the Arid Lands Symposium, Saltillo, Mexico.

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In Nevada, rodents were found to cache Indian ricegrass seeds in the soil; about half the seeds cached had the lemmas, paleas, and pericarps removed by the rodents. The removals greatly enhanced germination (McAdoo et al. 1983). Treatment with hormones (gibberelic acid and kinetin) also promoted germination in scarified seeds, but not in intact seeds (McDonald and Kahn 1977). Some seeds may require more than one year to reach the germination stage. Germination rates were found to increase with age up to 6 years, and gradually decrease with seeds up to 17 years old. Germination of 1 and 2 year old seed was enhanced by soaking in water at 2 - 4 degrees Centigrade for 40 days (Rogler 1960). In field conditions, seeds in all stages of seed coat deterioration and ripeness of embryo have been found in the soil under established stands (Robertson 1977). Winter precipitation and cold temperatures may provide the moisture and chilling necessary for successful germination. Artificial seeding is most successful if done in the fall before the onset of cold, wet weather (Charles H. Diebold pers. comm.).

Root systems on large vigorous plants extend up to 1.4 m downward and laterally, and provide substantial stability to loose soils (Hoover et al 1948). The deep extensive root system makes it possible for the plant to use moisture that would be unavailable to shallow rooted species. Indian ricegrass is drought resistant and tolerant of moderately alkaline soils. The grass provides good winter feed for livestock, due both to the nutritious seeds and high-protein foliage. Overgrazing (especially in the spring when the new growth and seedlings are particularly vulnerable) has considerably reduced the extent of this species over much of its range; reduction or elimination of grazing in the spring and early summer allows reproduction and food storage to take place, and the grass can then tolerate winter grazing without damage. As a forage grass, Indian ricegrass is particularly valuable in arid lands because of its capacity to grow and spread by natural processes in area where it is difficult for other grasses to become established (Hitchcock 1971, Hoover et al. 1948, Robertson 1977).

ARCHEOLOGICAL EVIDENCE FOR THE USE OF INDIAN RICEGRASS

Indian ricegrass was also a valuable resource to prehistoric human populations in the southwestern United States. Indian ricegrass seeds and pollen that closely resemble that of Indian ricegrass have been found associated with storage and cooking features in prehistoric archeological sites in the Southwest, especially in the Four-Corners area, where Utah, New Mexico, Arizona, and Colorado meet (figure 1). Pre-agricultural hunters and gatherers from the Archaic Period (6000 B.C. - 100 B.C.) were the first people to attempt to earn a living from arid lands in the Southwest. They are thought to have relied heavily on wild plant foods and small game animals. Because of the shallow and exposed nature of many structureless archeological sites from this period, botanical remains are often poorly preserved or entirely absent. However, occasional, reliable evidence for the use of wild plant foods has been found. In northwestern New Mexico, several deep pits associated with hearths dating to the late Archaic Period contained Indian ricegrass

seeds (Table 1, Toll 1985). Botanical evidence from later Anasazi times (100 B.C. - A.D. 1300) indicates that in addition to agriculture, people continued to rely on wild plant foods as a significant proportion of their diets (see Gasser 1982). The permanent structures associated with a more sedentary lifestyle afford much better protection for botanical remains, and considerable evidence for the prehistoric use of many wild plant species, including Indian ricegrass, has been found in New Mexico, Colorado, and Utah during this period (Table 1). In some of these sites, the seeds have

Table 1. The occurrence of *Oryzopsis hymenoides* seed and pollen resembling this species in archeological sites in the southwestern United States.

	Pollen	Float
Archaic Period Sites Ca. 5000 B.C. - 100 B.C.		
NW New Mexico		
NMAP Project	+	+ ^b
Anasazi and Fremont Period Sites Ca. 100 B.C. - A.D. 1200		
NW New Mexico		
NMAP Project	+	+ ^b
NIIP Project	+	+ ^b
Little Water		+ ^b
Tsaya		+ ^b
Pittsburgh Midway		+ ^b
Chaco Canyon		+ ^b
Salmon Ruin		+
Utah		
Danger Cave		+
Hogup Cave		+
Glen Canyon		+
Clyde's Cavern	+	+
Arizona		
Antelope House		+
Colorado		
Hoy House	+	+
Navajo Historic Sites		
NW New Mexico		
NMAP Project		

^aData from Bohrer 1980, Cully and Clary 1985, Fry 1975, Scott 1979, Stiger 1977, Toll 1981, 1985a, 1985b, Winter and Wylie 1975.

^bData summarized in Toll 1985b.

been found in a charred condition indicating parching or cooking, or uncharred in storage features or other proveniences suggesting purposeful introduction by man. Pollen from the Gramineae family is difficult to distinguish to the genus level, however, pollen that closely resembles that of Indian ricegrass has been found in archeological contexts. Both seed remains and *Oryzopsis*-type pollen have also been found in prehistoric coprolites (human fecal material), providing direct evidence of human consumption of this wild grass (Fry 1977, Fry and Hall 1975, Scott 1979, Stiger 1977, Toll 1981).

ETHNOGRAPHIC EVIDENCE FOR THE USE OF INDIAN RICEGRASS

Among native people in the southwestern United States, ethnographers have documented the historic importance of this species as a supplement to domesticated crops, and as a mainstay during times of poor crop production. The widespread record of human use from archeological and ethnographic data (figure 1) indicates the continuous use of this species, and also suggests the potential value of this wild crop for modern use (Jones 1938). In New Mexico, the Zuni people harvested the seeds and ground them into flour for bread. In times of food shortage, they searched the countryside to gather large quantities of the seed, and were seen bringing basketsful from as far away as 16 km (Castetter 1935, Stevenson 1915). Among the Hopi of northern Arizona, agriculture is also the primary means of subsistence, however, Indian ricegrass and dropseed grasses (*Sporobolus airoides*, *S. contractus*, *S. giganteus*) were regarded as staple wild plant foods. These grasses were preferred because of ease in harvesting; the ripe seeds fall readily from the plants. As with the Zuni, these grasses were especially important in times of agricultural failure. The importance of Indian ricegrass to the Hopi, at least in the past, is reflected by the naming of a clan for this species (Whiting 1939). Navajo people in northwestern New Mexico also used Indian ricegrass. The stems were gathered and the seeds collected by holding the grass near the fire. The thin pedicels quickly burned and the seeds fell to the base of a flat stone placed nearby. The seeds were then ground and made into cakes (Elmore 1944). Blankenship (1905 in Jones 1938), reported that seeds of Indian ricegrass were used by unspecified tribes in Montana. In Utah and Nevada, the Paiute people value Indian ricegrass greatly because it will grow in dry conditions in sand, and furnished food for man and forage for grazing animals. These people also traveled long distances to gather this esteemed food. The seed was ground into a meal and made into mush. The Paiute people also used harvested seed for replanting the range (Murphey 1959, Steward 1933). The Gosiute tribe also used Indian ricegrass (Mooney 1896, Chamberlain 1911). In Arizona, the White Mountain Apache people formerly used the seeds of this grass for food, but more recently the plant has been used only for hay (Reagan 1929). In California, the Koso, or Panimint Indians also gathered and used the seeds of Indian ricegrass (Coville 1892).

AN EXTENSIVE DUNE AREA DOMINATED BY INDIAN

RICEGRASS IN NORTHWESTERN NEW MEXICO

Actual cover values, plant densities and seed and forage yields for Indian ricegrass are scattered throughout various types of scientific literature. A study that a co-worker and I conducted in Northwest New Mexico can help to understand some of the conditions under which growth and reproduction of this species take place, as well as providing data on cover, density, and estimates of seed productivity (Cully and Clary 1982). In northwestern New Mexico, Indian ricegrass is a major component of the vegetation on extensive dunal deposits located south of the San Juan River. The dunes cover an area of about 2300 square km, and form the second largest dune field in New Mexico. The field is a thin mantle of aeolian sand with broad areas of exposed Cretaceous age sandstone and shale badlands. Much of the sand in the dune field is in the form of longitudinal dunes that trend in a northeasterly direction. Most of the dunes are between 0.8 - 3.2 km long. Distances crest to crest between dunes range from 90 - 450 m; the dunes are about 60 m wide and extend from 4 - 7 m above the interdunal surfaces. The sources of the dune sands are thought to be in-situ eroding of the sandstone beds and aeolian deposits brought by prevailing westerly winds from the adjacent Chaco river valley. The field is thought to be at least 6700 years old (Clary 1980, Hall 1970).

The dunes are well vegetated for the most part. Some are active along the crests, and recent aeolian activity occurs along the borders of the field where drainages incise. The sandy soils overlie less permeable clay or silt formations, producing excellent conditions for retaining precipitation. Moisture penetrates the upper, sandy permeable soils. The underlying impermeable layers keep the moisture from percolating to deeper levels, so that the moisture is then available for plant growth. Very little arroyo cutting is found within the field, although the area is surrounded by badland and sandstone outcrops. The elevation of the field ranges from 1757 - 1988 m. Precipitation averages about 17.8 - 25.4 cm per year. Most of the precipitation falls during late summer, but there is also an important component of winter and spring moisture (figure 2), that seems to be critical to the growth and reproductive success of *Oryzopsis*.

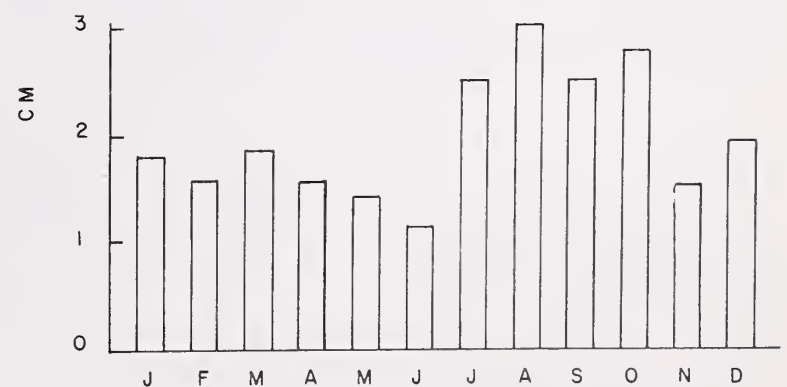


Figure 2. Monthly precipitation, Aztec Ruins National Monument, Northwestern New Mexico, 60 years of record (from Gabin and Esperance, 1977).

Our study area included approximately 37,344 ha of Navajo tribal grazing land that is being converted to sprinkle-irrigated agriculture. The water was allocated from the Navajo Dam on the San Juan River, and is carried by pipeline from river level to the higher plateau to the south. Our study accompanied an archeological survey and excavation that preceded road building, leveling, and grading activities, and was designed to produce data on vegetative dominants, cover, species composition, plant densities, and plant resources that may have been available to prehistoric inhabitants of the area. Our methods consisted of first stratifying, or dividing the study area into zones based on topography, soil, and constituent perennial plants. We used color aerial photography (1:3.680, Bureau of Land Management, Albuquerque Office), and USGS 7.5 minute topographic maps of the area to map vegetative zones. The sampling transects within these zones were located randomly. The line intercept method (Canfield 1941) was used to sample the vegetation because accurate and fairly complete information about a plant community can be obtained relatively quickly. Following Cox (1975) and Strong (1966), we estimated foliage cover or dominance, plant density, diversity, and frequency. We also took soil samples at the beginning and at the end of each transect.

We found that Indian ricegrass was most abundant on the dune crest and faces, while other grass species like galleta grass (*Hilaria jamesii*) dominate the interdune areas (table 2; figure 3). The soil samples indicated that the interdunal soils were silty sands, whereas the dunal soils were clean, coarse sands. Ricegrass appeared to be more successful in the coarser soils, and species more tolerant of fine soils were restricted to the swales between dunes.

During our survey, we also noted the presence of Indian ricegrass in all stages of growth from seedling to mature plants. Seedlings appeared to be the first plants to move into recently disturbed areas such as roadcuts, pipelines, and fences. This suggests that Indian ricegrass is an early colonizer of disturbed sandy soils and is well adapted to such conditions. This early colonizer may add substantially to soil stability and allow other species to become established later.

Based on foliage cover, Indian ricegrass was the dominant species in 6 of our 10 delineated vegetation ones (table 3), comprising most of the study area. *Oryzopsis* was a subdominant in 3 of the remaining 4 zones. The *Oryzopsis*-*Hilaria*-*Sporobolus* zone

Distribution of *Oryzopsis* on dunes and interdunes

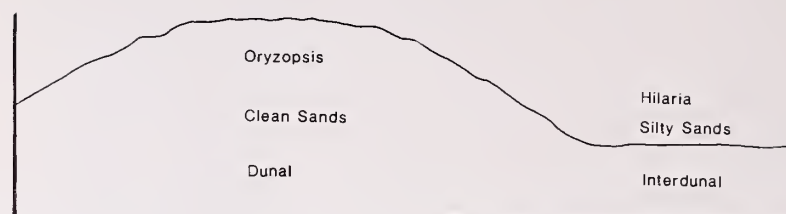


Figure 3. Distribution of *Oryzopsis hymenoides* in dunal habitats, northwestern New Mexico (from Cully and Clary, 1982).

contained by far the highest cover and densities of Indian ricegrass plants (table 3), almost 10 plants per square meter or 1000,000 per ha. This area is actually a small proportion of the total (table 3), but would have been an ideal area for prehistoric people to gather seed. Because of the high plant densities, there would be maximum reward for a minimum of energy expended in gathering. Based on estimates of seed production from other locations, this portion of the study area may produce approximately 116 kg of seed per ha (table 4). There are few comparable productivity data; what there are suggest that there is a great deal of variability between geographic locations, as well as high temporal variability. Plant densities were considerably lower at a study area in central Utah (Larralde and Chandler 1981); actual seed production was also lower than our estimates for northwestern New Mexico. During a year of favorable conditions in Nevada, the yield for about one-fifth the number of plants per ha was almost one-half the estimated yield in New Mexico (table 3; Young et al. 1983) suggesting that our estimates may actually be low.

Indian ricegrass is grown commercially, primarily for range reseeding and revegetating stripmined areas. While no plant densities are available, seed production data are (table 4). At Los Lunas, New Mexico, the mean of 13 years of production under cultivation (including irrigation and fertilizing at the rate of 100 lbs of ammonium nitrate per acre), was 620 kg per ha (Charles H. Diebold, pers. comm.). The data from northwestern New Mexico and Nevada suggest that, under suitable conditions, yields from untreated locations can be quite high,

Table 2. Centimeters of cover of 2 species from fine, interdunal soils to coarse, dunal sands along Transect 4, NIIP Blocks VIII-XI, northwestern New Mexico (from Cully and Clary 1982).

Species	Interval along transect - fine to coarse soils					Total
	1	2	3	4	5	
<i>Oryzopsis hymenoides</i>	84	46	148	179	249	706
<i>Hilaria jamesii</i>	22	21	33	0	0	90

Table 3. Total percent foliage cover, percent foliage cover of Oryzopsis hymenoides, density of Oryzopsis plants and percent of total area of each zone, NIIP Blocs VII-XI, northwestern New Mexico (from Cully and Clary 1982).

Zone	% Total Foliage Cover	% Foliage Cover <u>Oryzopsis</u>	Density per M ² <u>Oryzopsis</u>	Percent of Total Area
Or-Ep-Hi	39.4	17.6	3.0	8.7
Or-Sp-Sa	38.4	14.1	3.5	1.5
Or-Hi-Sp	37.7	27.6	9.7	0.8
Or-Hi-Ep	33.3	12.2	4.0	44.6
Hi-Bo-Or	31.5	4.0	1.2	7.8
Hi-Or-Gu	30.3	8.2	5.5	18.7
Sp-Ep-Ta	24.6	1.0	0.3	2.4
Or-Mu-Hi	23.2	9.2	1.6	1.0
Hi-At-Or	7.8	1.3	0.6	0.6
Or-Ep-Bo	33.6	12.6	3.4	14.0
Or = <u>Oryzopsis</u> At = <u>Atriplex</u> Hi = <u>Hilaria</u> Ep = <u>Ephedra</u> Sp = <u>Sporobolus</u> Ta = <u>Tamarix</u> Bo = <u>Bouteloua</u> Gu = <u>Gutierrezia</u>				

Table 4. Seed and forage yield estimates for Oryzopsis hymenoides.

Cultivated		Uncultivated	
Forage (kg/ha)	Seed (kg/ha)	Forage (kg/ha)	Seed (kg/ha)
Tos Lunas, N.M. ¹ 13 yr period	mean = 642.0 SE = 22.9	N.W. New Mexico ³ Estimates based on densities, one dunal site (9.7 plants/m ²)	116.0
Utah ² various ecotypes	452-5762	Utah ⁴ Yield on dunal site (0.5 plants/m ²)	10.3
		Utah ⁵ 3 yr period	mean = 25.6 SE = 9.7
		Nevada ⁶ Desert Queen Valley, 1 yr (1.7 plants/m ²)	63.8

¹Charles H. Diebold, pers. comm,

²Robertson 1977

³Cully and Clary 1982; Vogler 1982

⁴Robertson 1977

⁵Young et al. 1983

although irrigated and fertilized fields produce substantially larger quantities of seed.

Data on forage production also indicate substantial increases under cultivation (table 4). Geographic and temporal variability no doubt affect uncultivated forage as well as seed yields.

A REVIEW OF THE NUTRIENT VALUE OF INDIAN RICEGRASS

Several analyses of the constituents of Indian ricegrass indicate that the traditional value placed on this species is justified. The seeds are high in protein and calories, exceeding or equivalent to corn; the protein value of the forage is also high (table 5); the cured grass makes very good hay (Hoover et al. 1948). The seeds of other cultivated grasses (Sorghum sudanense, Secale cereale, Triticum aestivum, Zea mays; see table 5) are similar in protein values, but also have larger seeds and higher carbohydrate values. Most cereal crops are highly productive annuals, and have been selected over a long period of time for large seed size and high carbohydrate content. Indian ricegrass is a wild perennial grass that, in comparison to cereal crops, has undergone very little human selection.

Seed size and productivity may be improved by controlled breeding and hybridization, but production probably cannot reach the levels of the annual cereal crops. However, Oryzopsis will grow where other grasses cannot survive, and has the potential for productivity on otherwise unproductive land.

SUMMARY

Indian ricegrass is a native plant adapted to sandy soils in arid locations. The foliage is high in protein, and makes excellent winter forage for livestock. The large, nutritious seeds germinate and grow well in deep sands. With proper management, stands of Oryzopsis will reseed themselves naturally.

There has been a long tradition of use of Indian ricegrass by southwestern Indian people that

is documented in the archeological record and in ethnographic data from the late 1800s and the early 1900s. Modern analyses of nutritional value indicate that this long tradition of use is justified. Indian ricegrass has the potential for providing valuable nutritional supplements for man and forage for grazing animals in areas that would otherwise be non-productive.

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Table 5. Protein and caloric values of Oryzopsis hymenoides and some other grasses¹.

	Wt/1000 seeds	% Protein	Calories/g	% Carbohydrate
<u>Oryzopsis hymenoides</u>	2.4	Seed = 11.9-13.1 Foliage = 6.5-17.0	4058	25-39
<u>Sorghum sudanense</u>	7.7	11.9		
<u>Triticum aestivum</u>		14.2		
<u>Secale cereale</u>	20.7	17.1		
<u>Zea mays</u>	App. 400.0	10.0	4020	70

¹Data from Earle and Jones 1964, FAO 1953, Jones 1930, Kelrick and McMahon 1985, Schery 1972, Wolfe et al. n.d.

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Resumen.--Indian ricegrass Oryzopsis hymenoides (Roemer and Schultes) Ricker es una gramínea nativa adaptada a suelos arenosos en locales aridos. El follaje es alto en proteína y hace un forraje de invierno excelente para la ganadería. Las grande, nutritiva semillas germinan y cresen bien en arenas profundas. Habido una larga tradición del uso de Indian ricegrass por los Indios de suroeste que es documentado en recuerdos de arqueología y en datos etnográficos. Indian ricegrass tiene el potencial para proveer suplementos valiosos y natritivos para animales de pasto en areas que falta de oer productivas.

245 Values and Uses for Mesquite¹

S. Clark Martin²

Abstract.--Live mesquite can provide food and shelter for wildlife, domestic livestock and man but may displace more efficient plants in the process. Mesquite wood has many uses including domestic fuel and a possible source of energy for industry. To be economical mesquite products must compete successfully with available alternatives.

INTRODUCTION

Values and uses for mesquite include those of living plants and those of products derived from harvested mesquite. Living mesquite provides forage for domestic animals, habitat for wildlife, nectar for honey bees and protection from sun and wind for a variety of creatures. Also, mesquite pods have long been staple food items for desert peoples.

Mesquites (*Prosopis* spp.) occupy about 34 million ha of rangeland in the southwestern United States. Of this, some 22.7 hectares are in Texas, 1.62 in Oklahoma, 9 in New Mexico and Arizona and a smaller area in southern Nevada and California (Dahl 1982). The geographic distribution of mesquite apparently has not changed greatly within the last 150 years but it has increased greatly in density and cover within its range. Fluctuations in climate and in populations of rodents and rabbits, together with reduced incidence of range fires and heavy grazing by livestock have contributed to mesquite increase. In my view, the major influences are reduced density of perennial grass stands due to overgrazing and reduced incidence of fire.

Mesquite is found within the rainfall range of 8 to 75 cm, or more, from the western deserts of California to more mesic sites in Texas. Size of tree, and number of trees per hectare generally increase with rainfall or with available soil moisture. Growth form is also influenced by soil properties. It grows best on deep, well drained soils and does poorly where roots encounter dense, rocky clay near the surface. The largest mesquite are found along water courses and on flood plains where roots have access to available moisture

most of the year, especially where roots reach the water table. On upland sites that do not receive runoff and where annual rainfall is less than 50 cm, deep relatively sandy soils produce the largest trees but soils of finer texture grow more and bigger trees where rainfall is higher.

Mesquites are deciduous, thorny trees or large shrubs of the legume family. They are among the most evident and significant plants of arid and semiarid environments on both sides of the Mexico-U.S. boundary. All mesquites belong to the genus *Prosopis* but authorities don't agree whether the recognized subgroups are species or varieties. Benson, in Benson and Darrow (1981), states that "...character combinations of mesquite populations are inconsistent, amazing and bewildering. Regardless of speculation concerning the origins of the present populations, they interbreed, and their distinctions are inconsistent." Benson includes all mesquites in *P. juliflora* (Swartz) D.C. and distinguishes five varieties (Table 1). On the other hand, Johnston (1962) distinguishes three species; *velutina*, *glandulosa*, and *articulata*. Benson states that "Questions of classification are rarely settled, and this one never will be." Thus, the common names for the generally recognized sub-populations of mesquite are more persistent and stable than their Latin equivalents.

VALUES AND USES OF LIVE MESQUITE

Mesquites vary greatly in growth form and occur in stands of varying densities. The uses that are made of these stands, or of individual trees, depend not only on the character of the mesquite but on the products people obtain from them. Mesquite is valued for livestock forage, food production and environmental enhancement. These positive values often are offset to some extent by negative attributes or influences.

¹Paper presented at the reunion sobre manejo y utilizacion de las plantas aridas (meeting on management and utilization of arid land plants. [Saltillo, Coahuila, Mexico, February 18-22, 1985])

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in other ways, was a staple food with the Pimas and still is eaten by them to some extent. Fermented Pinole was a favorite intoxicating drink."

Recent evaluations of mesquite pods for human consumption indicate that the protein content of the seed is similar to that of soybean but higher than some other legumes (Zolfaghari and Harden 1982). Proximate composition of mesquite beans were determined by these authors (Table 2). Feeding tests showed that mesquite seeds provided nitrogen sufficient not only for maintenance but for partial growth of weaning rats. Mesquite beans were considered to be good sources of Ca, Mg, K, Fe, and Zn. Becker (1982) found protein from mesquite seed was deficient in sulfur amino acids but generally similar in nutritive value to other common legumes. On the other hand, pod pericarp contained little protein and was considered valuable mainly for its unique taste and high fiber content.

Table 2. Proximate composition of mesquite beans (From Zolfaghari and Hardin).

Sample	Components (dry weight basis)				
	Protein (n x 6.25)	Crude fat	Ash	Crude fiber	Total carbohydrate
	- - - - - (Percent) - - - - -				
Green fruit	13.26	2.23	3.88	35.33	80.63
Mature fruit	13.35	2.87	3.40	24.73	80.38
Seed	39.34	4.91	3.61	6.86	52.14
Pericarp	7.02	2.08	3.62	29.63	87.08

Meyer, Becker and Neukom (1982) divided mesquite pods into major fractions, determined their major chemical components and listed possible uses for each (Table 3). They prepared "acceptable" cereal products such as bread and cookies that contained Prosopis fractions. Lack of starch in Prosopis pods required addition of starch from other sources. However, they felt that addition of Prosopis flour could enrich diets where the staple foods such as casava are nutritionally poor. The word "acceptable" as used earlier in this paragraph suggests that, for most of us, food products prepared from mesquite pods would be novelties rather than foods of choice.

The most widely used food product derived from mesquite is honey. Mesquite is rated by many bee producers as the most valuable honey plant in Arizona. Consequently, beekeepers are opposed to large scale mesquite control projects designed to increase grass production.

Available data on production of mesquite pods is limited. Cornejo et al. (1982) report that production of mesquite beans is strongly correlated with crown diameter within the rainfall range from 111 to 280 mm per year. Using the average number of pods per tree over a period of two or more years, they established the equation $Y = 593.44x - 1033.57$ ($r = 0.823$) where Y is the number of pods/tree and x is crown diameter of the tree in meters. They estimate that a mature orchard with 118 trees/ha with crowns 8 m in diameter would yield 2300 kg/ha of pods per year. To obtain such yields would require irrigation as yields of velvet mesquite pods on upland sites with 300 mm annual rainfall has been reported to be about 14 kg/ha (Barth and Klemmedson, 1982; Parker and Martin, 1952).

Environmental Enhancement

The visual quality of unbroken grassland is improved by scattered trees or patches of mesquites. The grass-mesquite complex provides visual variety and the trees offer shade for livestock and

Table 3. Fractions of Prosopis pods: main components and possible application (From Myer, Becker and Neukom 1982).

<u>Fraction A</u>	<u>Fraction B</u>	<u>Fraction C</u>	<u>Fraction D</u>
Exo-mesocarp 55%	Endocarp 25%	Endospermsplits 10%	Cotyledon 10%
<u>Main Components</u>			
Sucrose 30-40%	Fiber 35-45%	Galacto-	Protein 60%
Fiber 15-20%	Protein 8-12%	Mannan 50-70%	Fat 8-12%
<u>Possible Application</u>			
Ethanol Production	Food Products	Gum	Protein
Sucrose Extraction			Concentrate
Food Products			

Table 1. Geographic distribution of the common varieties of mesquite, *Prosopis juliflora* (Swartz) D.C. in the United States and Mexico (From Benson and Darrow 1981).

Common Names	Variety Name and Distribution
Mesquite	var. <i>juliflora</i> ; Mexico and the West Indies. Not in Continental U.S. except by introduction.
Velvet mesquite	var. <i>velutina</i> (Wooton) Sarg.; Arizona to northern Sonora. var. <i>articulata</i> (S. Wats.) Wiggins; Southern Baja California and west central Sonora. Similar to velvet mesquite except the pods are compressed and constricted between the seeds.
Western honey mesquite	var. <i>Torreyana</i> L. Benson; south central and southern California; southwestern Arizona; southwestern New Mexico; along the Rio Grande from El Paso to the Big Bend in west Texas; Baja California to Sinaloa and the northern Mexico Plateau.
Honey mesquite	var. <i>glandulosa</i> (Torrey) Cockerell; southwestern Colorado to Kansas, Texas and northeastern Mexico.

Livestock Forage

The flowers and pods of mesquite are relished by domestic livestock. Flowers provide forage for only a short time but pods may be consumed over a much longer period since pods can be picked up off the ground long after they mature. However, cattle and horses can develop serious digestive problems if forced to subsist entirely on dried mesquite pods. On many ranges pods are an unreliable forage crop at best because production varies greatly from year to year. Mesquite leaves are not highly palatable but are relatively high in nitrogen, and therefore nutritious. Regrowth from stumps provides some forage even in areas that have been cut over. The value of mesquite as a browse plant is limited because it is deciduous and does not provide green foliage during winter and early spring when grasses are most deficient in nutrients.

Cattle do not thrive on a diet of mesquite alone except for brief periods when flowers and/or fruits are available. Historically, however, mesquite leaves have served as maintenance forage and kept animals alive in late spring after grass forage was gone. In southern Arizona, for example, where 90 percent of the perennial grasses forage is produced during the summer months, the old grass forage often was eaten up by late winter long before July rains brought new growth. In this situation mesquite that leafed out in April or May was a lifesaver. In some years flowers and pods added strength to the diet a few weeks later.

The value of mesquite forage is usually offset entirely, or partly, by reduced grass production. Several studies on the Santa Rita Experimental Range in Arizona show dramatic increases in grass production following mesquite control. Park and Martin (1952) showed that average yields of perennial grasses, 1941-1948, were 58 kg/ha in mesquite stands and 122 kg/ha where all mesquite was killed. Martin (1963) thinned 0.8 ha plots to leave varying numbers of mesquites at four sites ranging in mean annual rainfall from 30 to 43 cm in 1945. Fourteen years after treatment grasses on completely cleared plots outyielded the full stands by 4 to 6 times at the two higher rainfall sites and by 10 to 13 times at the lower rainfall sites. At the lowest rainfall site the 62-tree per ha plot produced only one fifth as much perennial grass as the 0-tree plot. At the three higher rainfall sites yields on the 62-tree plots were about 44 percent of those for plots completely cleared. These were closely controlled tests where mesquite was relatively dense and evenly spaced and follow-up treatments prevented reestablishment of mesquite on the thinned and cleared plots.

In pasture-wide tests where control was not complete and where initial stands were spotty the responses of grasses following mesquite control were less dramatic. Cable and Martin (1975) reported that cleared pastures produced 52 percent more perennial than mesquite infested pastures. In another study (Martin and Cable 1974) mesquite control increased perennial grass production by 43 percent. These increases are similar in magnitude to those reported by Dahl (1982) for various tests in Texas where aerial spraying with 2,4,5-T was the usual control method and where the reduction in density and crown cover of mesquite was variable. Dahl reported that increases in grass production increased with the degree of control, but that under the more mesic conditions in Texas 62 mesquites/ha had little impact on grass production. In Arizona, 62 evenly spaced mesquites per ha reduced grass production by half.

Rational decisions on the merits of mesquite control must weigh the advantages of having emergency forage at the time when grasses most often are deficient in quantity and quality against the possibility that there might be more than enough grass forage to carry the animals if the mesquite were not there. An obvious compromise would be to leave a few widely spaced mesquites or scattered patches. The mesquite could provide emergency forage and shelter from sun and wind without seriously reducing forage production.

Food for Human Consumption

A brief summary of human uses for mesquite is provided by Kearny and Peebles (1953):

"This plant has been a mainstay of existence to the aborigines of the Southwest. When cultivated crops failed, the Indians subsisted mainly on mesquite beans. Pinole, a meal made from the long sweet pods prepared in the form of cakes and

wildlife, perching and nesting sites for birds and escape cover for deer, peccary and other wildlife.

Mesquite also enriches the soil, at least locally. Tiedemann and Klemmedson (1973) found that organic matter, total nitrogen, total sulfur and total soluble salts were up to three times greater in the surface 0 to 4.5 cm of soil under mesquite crowns than in soil in openings and that bulk density under trees was lower. Jarrell et al. (1982) reported that symbiotic N fixation by mesquite is widespread, makes substantial inputs into mesquite-dominated ecosystems, and recommended that mesquite should be inoculated if planted where suitable indigenous rhizobia do not exist. Shoustari and Pepper (in press) in Arizona found that indigenous bacteria associated with mesquite were more aggressive in entering root hairs and fixed more nitrogen than did commercially available mesquite inoculant.

Barth and Klemmedson (1982) found that velvet mesquite accumulated N at the rate of 11.2 g/m^2 per meter of height and C at the rate of 0.11 kg/m^2 per meter of height. These findings help explain the greater abundance and improved growth of perennial grasses observed under mesquite. Tiedemann and Klemmedson (1977) found cover of perennial grasses under velvet mesquite was 24 percent compared to 4 percent in the open. Similarly perennial grass biomass was 1146 and 239 kg/ha in canopy and open zones, respectively. However, since less than 20 percent of the area is covered with mesquite the weighted average biomass would be no more than 420 kg/ha. Average perennial grass production for several years on mesquite-free plots at two similar sites was 552 kg/ha Parker and Martin (1952).

There can be little doubt that mesquite in the presence of suitable rhizobia can and does fix atmospheric nitrogen although nodules indicating presence of nitrogen fixing bacteria are rarely found on mesquite growing naturally. The fact that soil under mesquites is more fertile than soil in the openings is also indisputable. However the evidence is strong that much of the increased fertility under mesquites is attained by draining nutrients from nearby openings. Soil under mesquite crowns is enriched by leaf fall and by organic matter swept from spaces between trees by the wind. Also, mesquite roots extend far beyond the edge of the crown and gather both moisture and nutrients from the openings. In most mesquite stands these processes enrich less than 20 percent of the soil surface at the expense of the remainder. It is by no means certain that symbiotic nitrogen fixation by mesquite results in a net gain in the nitrogen economy of grassland soils as mesquite invades.

Afforestation

I have had the experience of showing scientists from such areas as India and Pakistan the detrimental effects of mesquite on the Santa Rita Experimental Range only to receive a letter some-time later requesting mesquite seed for planting. These requests come from areas where fuel for

domestic use is very scarce and there is a real need for any kind of a plant that will produce wood for cooking fuel or other domestic use.

Mesquite (*P. juliflora*) is being evaluated for sand dune stabilization in Saudi Arabia (Abohassan 1978). This seems to be a logical application since sizeable tracts in Arizona and New Mexico are occupied by mesquite sand dunes.

Negative Attributes

The primary objection to mesquite where it occupies former grassland is that ground cover is reduced and erosion is accelerated. Martin³ found that mesquite control reduced the rate of loss of surface soil by two thirds during the period from 1974 to 1983. Reduced surface erosion was also reported by and Parker and Martin (1952). Reduced ground cover lets non-forage plants become established in space previously occupied by grasses. Mesquite generally makes the site drier and reduces the amount of moisture available to prime forage plants. Mesquite competition is especially severe during the late spring and early summer when mesquite leafs out on accumulated cool-season moisture long before the warm-season perennial grasses begin rapid growth. Moisture used by mesquite at this time creates a moisture deficit that must be replenished by early summer rains.

The detrimental effects of mesquite on grass forage production is often aggravated by increases in populations of rabbits and rodents. These small animals can consume enough forage and seed on seriously depleted ranges to greatly retard or prevent restoration of the grass stand even if domestic animals are removed. Moreover, as the process of deterioration continues, the quantity of available grass decreases and domestic animals are forced to rely more and more on mesquite.

VALUES AND USES FOR HARVESTED MESQUITE

Mesquite may be harvested for use on the site or transported to other locations for processing and use. Since mesquite on the range has been considered a weed rather than a crop few measurements of standing biomass or annual production are available. Barth and Klemmedson (1982) determined the distribution of dry matter (Table 4) which suggests the yield of dry wood from velvet mesquite to be 22 metric tons/ha on an upland site in Arizona with 30 cm annual rainfall. Cornejo et al. (1982) estimated wood yield in the Alter Valley southwest of Tucson to be 12 metric tons per hectare for riparian habitats and 5 metric tons/ha on non-riparian sites.

In a review of available data for the Texas Rolling Plains Dahl (1982) reported that dry wood production by mesquite was about 2, 12, and 22 metric tons per hectare for shallow upland, deep upland and bottomland sites respectively. These

³Martin, S. Clark, unpublished data from Santa Rita Experimental Range.

One-time yields tell us nothing about annual yields or rate of regrowth. Dahl also cites a report by Wright and Stinson (1970) which indicated that annual growth on uncut trees was about 1.8 kg compared to 0.4 kg on trees with tops removed. Assuming 600 trees per hectare this would amount to 1080 kg/ha on uncut trees compared to 240 kg/ha of regrowth from stumps. There is a real need for better information on actual and potential yields of wood from mesquite throughout its range.

Table 4.--Amount and distribution of dry matter in 34 velvet mesquite trees with average height 3.3m and crown area 20.9m². Dry matter per ha values assume 200 plants/ha (From Barth and Klemmedson 1982).

Component	Kg/shrub	Kg/ha
Shoot		(200 plants)
Leaves	3.24	648
Flowers	0.04	8
Fruit	0.07	14
Current twigs	0.26	52
Small branches (<1cm)	8.25	1,650
Large branches (>1cm)	75.92	15,184
Deadwood	26.36	5,272
Subtotal	114.14	22,828
Roots	15.44	3,088
Total Plants	129.58	25,916

Raw Wood

Seasoned mesquite wood is commonly used for fence posts, domestic fuel, furniture, crafts, and construction in buildings, corrals, even fishing boats. Heartwood of mesquite is dark brown, moderately hard and has been used for many products that commonly are made of walnut. Examples include furniture, gunstocks, craft items. Mesquite has limited use in construction because most stems are not long enough and straight enough for lumber. Even so, I saw mesquite used for construction of the frame work for fishing boats at Punto Penasco, Sonora. Slabs of mesquite were keyed together to form the framework.

Processed Wood

There is a rather large market for charcoal in the United States. A number of specialty restaurants even in the Northeastern U.S. feature mesquite-broiled steaks. Mesquite could provide much more of the charcoal for backyard barbequeing than it now does.

Mesquite wood may also be ground and processed into feed for cattle where it may be substituted for cottonseed hulls or similar roughage (Bryant et al. 1982; Tock 1982). Wood molasses may also be

derived from mesquite and used as a forage supplement. Other products that may be made from mesquite include paper and particle board. Chemicals include: gums, tannins, alcohols or derived medicines (Parker (1982)). All of these uses for mesquite are technically possible but most of them are not economically feasible at present.

Mesquite is being evaluated as a source of energy for industry. Two possibilities include: (1) petroleum extraction (Parker (b) 1982) and (2) generation of electricity (Smith 1982). A major shortcoming of mesquite for such industrial uses is the low yield of wood. Mesquites, generally, yield a small amount of wood per tree, stands are often sparse and harvesting costs are high.

A mobile mesquite harvester designed to cut whole trees at the ground surface reduce them to small pieces or chips and elevate these into a basket where they can be dumped into a truck has been pilot tested (Ulich 1982). The cost of harvesting green mesquite with this machine is estimated to be \$8.21 per 1000 kg of green wood; about half the cost for other methods now in use.

CONCLUSIONS

Mesquite generally reduces carrying capacity for livestock, accelerates sheet and gully erosion, and increases the cost of handling range livestock. I feel that mesquite control is an essential range management practice just as weed control is necessary in row-crop agriculture.

The essential demands for live mesquite for emergency forage, honey production, wildlife habitat, shade and scenic beauty usually can be met with much less than a full and complete stand of mesquite. Scattered trees and/or alternating patches of mesquite and open grassland may be the best multiple-use compromise.

The current value of mesquite wood for domestic and/or industrial use doesn't always pay the cost of harvesting. Such uses may be feasible, however, if increased forage production offsets part of the harvesting costs. Conversely, returns from the sale of wood may make mesquite control feasible for range improvement.

The use of mesquite pods for human food is more novel than practical except in primitive cultures during periods of extreme food scarcity and where mature stands of mesquite already exist. Where mesquite stands must be established, the need for wood for domestic use may be so great that mesquite trees will be cut for fuel long before they are old enough to bear high yields of pods.

With effective promotion the market for mesquite wood chips and/or charcoal for home and restaurant barbeque cooking in the United States can probably be expanded.

As with other commodities the market for

mesquite wood, for whatever purpose, will be strongly influenced by the availability, cost and quality of competing products.

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Resumen.--Mezquite puede proveer comida y resguardo para fauna silvestre, ganaderia y humano pero tambien puede desplazar plants que son mas eficiente en el proceso. Leña de mezquite tiene muchos usos incluyendo combustibles domésticos y como alternativa de energía para industria. Para acer económico, productos de mezquite tienen que competir con buen éxito con disponible alternativos.

245 Alternativas de Industrialización de la Gobernadora¹

Baldemar Motomochi B.²

Resumen.--La gobernadora (Larrea tridentata) es un recurso de gran abundancia en las zonas áridas y semiáridas de México. En el presente trabajo, se presentan algunas generalidades de este recurso y los diferentes usos potenciales para el mismo. Se presentan también dos opciones de industrialización que están siendo estudiadas en el Centro de Investigación en Química Aplicada (CIQA), los resultados obtenidos y las conclusiones al respecto.

INTRODUCCION

La gobernadora, nombre descriptivo utilizado en México para la Larrea Tridentata, es una de las plantas características y de mayor abundancia en las zonas desérticas y semidesérticas del país.

La gobernadora es una planta que presenta diferentes aspectos de gran interés que van desde los complejos mecanismos fisiológicos y sofisticadas estrategias defensivas, base de su gran capacidad de adaptación, hasta el gran número de posibilidades que este recurso ofrece como fuente potencial de materias primas en la elaboración de productos diversos de uso industrial o final.

Un considerable esfuerzo de investigación ha sido desarrollado en diferentes instituciones nacionales e internacionales, que ha permitido elevar el conocimiento sobre este recurso y establecer las bases para la búsqueda de opciones de industrialización.

LA GOBERNADORA COMO FUENTE DE MATERIAS PRIMAS Y MATERIALES

El arbusto de gobernadora tiene una gran variedad de sustancias químicas tales como ceras, compuestos volátiles y compuestos fenólicos. Se reportan más de cien compuestos químicos identificados de los cuales el 83 al 91% son de tipo fenólico (Lignanos y Flavonoides).

Además de los compuestos químicos presentes, este recurso ofrece otros materiales de interés como lo son el material celulósico y las hojas que contienen un nivel importante de proteína (16-19%).

¹ Ponencia presentada en la Reunión Sobre Manejo de Plantas en Zonas Áridas. Saltillo, Coahuila, México. Febrero 18-22, 1985.

² Ing. Químico, Jefe del Depto. de Ingeniería y Desarrollo del CIQA, Saltillo, Coahuila, México.

Existen antecedentes de la utilización de este recurso con fines comerciales tal como lo fue la obtención de ácido Nordihidroguayarático (NDGA) para su uso como antioxidante en grasas, vitamina A, salmón, etc. El NDGA fue producido por 25 años a partir de Gobernadora hasta que en 1942 fue declarado producto dañino para la salud por la FDA en Estados Unidos.

USOS POTENCIALES

En la figura 1 se muestran las diferentes opciones técnicas de utilización de las sustancias y materiales presentes en la Gobernadora. En esta figura se resumen los diferentes usos posibles para este recurso, de acuerdo a investigaciones llevadas a cabo por diferentes instituciones en México y otros países.

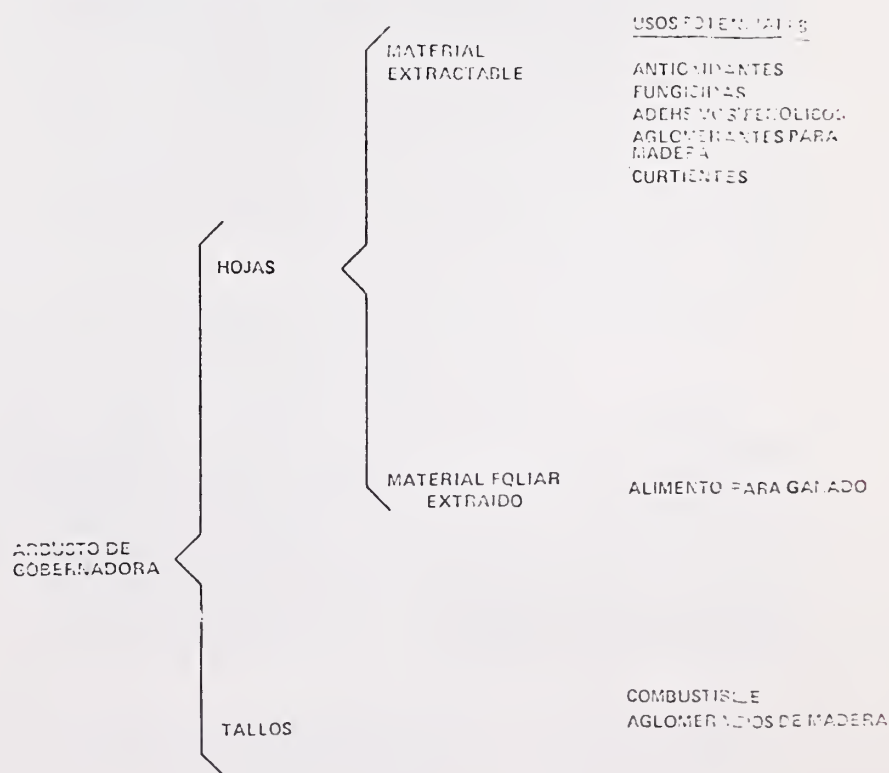


FIGURA 1. USOS POTENCIALES REPORTADOS PARA LOS DIFERENTES MATERIALES PRESENTES EN EL ARBUSTO DE GOBERNADORA

OPCIONES DE INDUSTRIALIZACION

El aprovechamiento industrial de la Gobernadora plantea una serie de aspectos que deben tomarse en consideración para el diseño de las opciones técnicas y económicas en dicho aprovechamiento. Entre estos aspectos se pueden mencionar los siguientes:

- La Gobernadora es un recurso silvestre aún no domesticado disperso en el 25% del territorio nacional.
- Las operaciones de recolección, densificación y transporte de recursos silvestres con contenidos bajos de los materiales de interés, normalmente involucran altos costos y requieren de una buena organización para cubrir satisfactoria y oportunamente las necesidades de abastecimiento.
- La gran cantidad de compuestos químicos presentes en la Gobernadora impone serias restricciones para su aislamiento y recuperación en productos puros.
- La economía de escala en los sistemas de producción en base a recursos naturales silvestres del tipo de la Gobernadora, se ve reducida al no poderse contar con instalaciones de gran capacidad dado que se incrementaría notablemente el esfuerzo de transporte (radios de acción mayores) y el costo de la materia prima puesta en planta.

Ante estos y otros muchos factores a considerar, se requiere de la definición de una estrategia que permita minimizar las desventajas y maximizar los beneficios para hacer factible técnica y económicamente la explotación industrial del recurso.

Tomando en consideración alguno de los aspectos antes mencionados y fundamentándose en información generada a nivel laboratorio, el CIQA ha venido realizando algunos programas de investigación y desarrollo tendientes a encontrar opciones para la industrialización de la gobernadora. Básicamente se ha venido trabajando en dos opciones; la obtención de resina de Gobernadora para su utilización como antioxidante de hules y plásticos y, la obtención de resina de Gobernadora para su utilización como curtiente de pieles.

RESINA DE GOBERNADORA COMO ANTIOXIDANTE DE HULES Y PLÁSTICOS

Diferentes pruebas de aplicación han sido llevadas a cabo y en las que se ha demostrado que la resina de Gobernadora puede ser utilizada como anti oxidante de hules y plásticos (hule natural de Guayule, SMR-5, NATSYN, PB, SBR y polietileno) tanto en su almacenamiento como en la elaboración de productos terminados. Se ha encontrado una equivalencia con productos comerciales tales como el T.Q.P., BLE 25, AMINOX 25, etc.

Paralelamente a las evaluaciones de aplicación del producto se realizaron estudios del

proceso de extracción y purificación de la resina de Gobernadora como antioxidante. Mediante el proceso desarrollado se pretende fraccionar la resina de Gobernadora contenida en las hojas y utilizar únicamente el extracto alcoholico de la misma.

Se han realizado estudios complementarios (mercado, costos, disponibilidad de materia prima, etc.) que han permitido hacer análisis preliminar de la factibilidad de instalación de una unidad industrial de producción con una capacidad de 1000 toneladas de resina antioxidante por año. Dicha capacidad fue establecida en base a la posibilidad de exportar el producto al mercado Europeo y en la cantidad de materia prima disponible en un área aproximada de 8000,000 Has. estudiada para abastecer a dicha planta.

Los analisis económicos realizados sobre esta opción permiten establecer los siguientes puntos:

- La rentabilidad en la producción de 1000 toneladas por año de resina antioxidante es baja, si se considera a la resina como el unico producto de valor comercial.
- Derivado del punto anterior, es necesario aprovechar los subproductos de proceso, principalmente la hoja (4,200 tons/año).
- Poblaciones de mayor concentración en el recurso silvestre podrían reducir notoriamente los costos de la materia prima puesta en planta y por lo tanto el costo de producción (la materia prima, hoja de Gobernadora representa alrededor del 40% del costo de producción).

Actualmente se realizan investigaciones sobre las posibilidades de utilizar la hoja desresinada en la alimentación de animales, para ver las posibilidades técnico-económicas que una unidad industrial de producción pudiera tener en terminos de un aprovechamiento más integral del recurso.

RESINA DE GOBERNADORA COMO CURTIENTE DE PIELES

Durante 1983 México importó 10,455 toneladas de curtiente de origen vegetal que cubrieron las necesidades de la industria de la curtiduría. En 1981 se importaron 17,164 toneladas del mismo material (Quebracho y Mimosa).

Actualmente este sector industrial a reducido notoriamente su capacidad en la curtición de pieles, debido principalmente a la imposibilidad de importar estas materias primas al ritmo y cantidades requeridas para su operación normal.

Pruebas llevadas a cabo a nivel laboratorio sobre la obtención de resina curtiente a partir de Gobernadora, así como pruebas de aplicación de la resina obtenida, han establecido las bases para el estudio de una nueva opción de aprovechamiento industrial de este recurso.

Análisis preliminares de las posibilidades técnico-económicas de esta opción muestran mejores perspectivas para la resina de gobernadora curtiente que los encontrados para la resina de gobernadora antioxidante. Los trabajos de investigación y desarrollo planteados para el año en curso, así como estudios adicionales que se realizarán, permiten suponer que para finales de este mismo año, podrá ser posible conocer la factibilidad de producir a nivel industrial, resina de gobernadora curtiente.

CONCLUSIONES

La Gobernadora es un recurso natural que ofrece un gran número de opciones para su aprovechamiento. La gran variedad de productos químicos presentes, representan un gran reto a la capacidad técnica y al diseño de opciones para su industrialización y generación de productos con interés comercial.

En el caso de las dos opciones presentadas, el aprovechamiento de los subproductos principalmente el de la hoja desresinada, es determinante para la obtención de mayores márgenes de utilidad que hagan más atractiva la instalación de unidades industriales de producción.

En base a los resultados y evaluaciones hechas sobre estas opciones y a la experiencia tenida con otros recursos similares, es posible establecer cuatro aspectos que deben ser considerados en cualquier estrategia para la industrialización de recursos similares:

- Aprovechamiento integral del recurso.
- Integración vertical a través del desarrollo de productos de mayor valor agregado.
- Incremento de las densidades o número de plantas por Ha del recurso.
- Investigación y desarrollo.

En la medida en la que estos factores puedan ser incluidos positivamente en los planteamientos para la explotación de esta tipo de recursos, mayores serán las posibilidades de contar con sistemas agroindustriales eficientes que permitan explotar adecuadamente nuestros recursos naturales renovables y se conviertan en verdaderos polos de un desarrollo económico y social sostenido en las regiones áridas y semiáridas de nuestro país.

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Summary.--The Creosotebrush (*Larrea tridentata*) is a resource of great abundance in arid and semi arid lands of Mexico. This report presents some general outlines of this resource and the different potential uses of it. We also present two industrialization options that are being studied at the Centro de Investigación en Química Aplicada (CIQA), as well as the results and conclusions to this report.

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Aprovechamiento Industrialización y Comercialización de las Palmas "Corriente," "Del Istmo," y "De Chilapa" en el Desarrollo de las Comunidades Indígenas de la Región de la Mixteca¹

Lic. Octavio García Rocha²

Resumen.--La empresa de Participación Estatal Fidepal, S. de R. L. de I.P. y C.V., fue creada por Decreto Presidencial en 1973, con el fin de mejorar las condiciones sociales y económicas de la población que habita en la región de las Mixtecas en los estados de Oaxaca, Puebla y Guerrero, y la Meseta Tarasca en el estado de Michoacán. En el seno de este organismo se crearon los primeros Comités de la Palma, organizaciones de tejedores y recolectores de esta fibra natural que constituyen la base para la creación de Sociedades de Solidaridad Social para la industrialización y comercialización de las artesanías de palma, mismas que ahora integran Fidepal y sus unidades de Producción.

GÉNEROS Y ESPECIES DE LA PALMA

En México existen dieciocho géneros de palmas nativas que agrupan sesenta especies. Siete géneros comprenden palmas de hoja en forma de abanico, mientras que las once restantes se caracterizan por contar con hojas que semejan una pluma.

Las palmas por lo general se localizan en regiones de clima tropical y subtropical. Sus particularidades más sobresalientes son su tallo simple y cilíndrico que puede ser liso, áspero o espinoso. En su parte inferior cuentan con raíces fibrosas y en la superior poseen un penacho de hojas., además de que sus flores son pequeñas, poco vistosas y sus frutos son variados.

Algunas especies son de importancia económica por sus variadas aplicaciones. Por ejemplo, los habitantes de las costas utilizan el tallo para la construcción de las armazones de sus chozas y las hojas para el techo de las mismas. En otros casos, el jugo del tallo contiene cierto tipo de azúcares que por el proceso de fermentación se convierte en una bebida alcohólica. Los frutos de algunas variedades como las de la "Palma de Coco", "Palma de Corozo", "Palma de Coyol Real" son comestibles, además de que bajo ciertos procesos se obtienen aceites de uso industrial. Mediante la utilización del cogollo de la "Palma de sombrero", de la real y de Jipi" se elaboran diferentes clases de sombreros, cestos, petates, cordeles, cintas, telas, etc.

¹ Ponencia presentada en la Reunión Sobre Manejo de Plantas en Zonas Áridas. Saltillo, Coahuila, México. Febrero 18-22, 1985.

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Las palmas utilizadas en el tejido del sombrero pertenecen a la familia de las Palmáceas y se agrupan en los géneros Brahea, Sabal y Carludovica. Para el tejido, indistintamente en los tres géneros, solo se emplea el "Cogollo" o yema foliar de la planta.

Género Brahea

El Género Brahea agrupa las especies Calcareia, Conzatti, Berlandieri, Decumbes y Dulcis siendo esta última la única que se emplea para la manufactura del sombrero.

La Brahea Dulcis se caracteriza por contar con un tronco ó estipe que alcanza hasta más de diez metros de altura, sus peciolos dentados en los bordes miden hasta sesenta centímetros de largo y se encuentran cubiertos con una especie de lana fina de color blanco que se extiende hasta los limbos de las hojas tiernas y a las inflorescencias. Los limbos de las hojas son palmados es decir, en forma de abanico circular y miden hasta ochenta centímetros de largo, las flores de color blanco apenas alcanzan los dos milímetros de extensión mientras que el fruto es ovalado de aproximadamente nueve milímetros de largo, de color verde cuando tierno y café negruzco al madurar. Esta especie de palma generalmente se desarrolla en altitudes que varían de 600 a 2 200 metros sobre el nivel del mar y se localiza en regiones de los estados de Oaxaca, Guerrero, Puebla, Veracruz, Morelos, Hidalgo, Querétaro y San Luis Potosí.

En la región Mixteca de Oaxaca existen palmares de esta especie en los poblados de Huajuapán, Nochixtlán y Silacayoapán, así como en la parte norte del distrito de Coixtlahuaca y sur

de los distritos de Tlaxiaco y Nochixtlán. Los palma res cercanos a los centros urbanos o rurales de esa región presentan características de sobre explotación a tal grado que excepcionalmente alcanzan los seis metros de altura, sus "cogollos" son pequeños y de mala calidad. Esto ha propiciado que los campesinos tejedores la denominen "Palma Corriente" o "Anicera" y que sus cogollos de coloración verdosa se utilicen en la manufactura de los sombreros corrientes o "Aniceros", así como también en la elaboración de petates, mecates y colotes. Los bosques de palma existentes en las partes sur de los distritos de Silacayoapan, Tlaxiaco y Nochixtlán alejados de los centros urbanos y rurales han sido poco explotados. El cogollo de estos lugares es el mejor cotizado y por lo general se le conoce como "Palma Fina".

Es conveniente mencionar, que a la especie *Brahea Dulcis* se le conoce con diferentes nombres vulgares, tales como Palma Corriente o Anicera, Palma Fina, Palma Blanca, Palma Jaltepec, Palma de Sombrero, Palma de Yosondúa o Palma de Silacayoapan. En los bosques de palma del municipio de Santiago Tilantongo, Oax., la *Brahea Dulcis* se mezcla con las especies *Brahea Calcareo* y *Brahea Conzatti*. A estas dos últimas se les conoce con el nombre vulgar de palma ceniza y plama de agua respectivamente, pero son escasas y por lo general se emplean para la elaboración de escobas.

Género Sabal

Este género agrupa veintiseis especies de las cuales en México solo se localizan las denominadas Duguesii, Mayárum, Yapa, Yucatánica, Uresana, Rosei, Texana y Mexicana, siendo esta última la que se utiliza en la manufactura de sombrero.

La Sabal-Mexicana se caracteriza por contar con un tronco o estipe que alcanza hasta veinte metros de altura, sus peciolos son lisos y miden alrededor de un metro, los limbos son costal-palmados, es decir, en forma de abanico curvados hacia abajo y miden alrededor de un metro. Las flores son casi blancas y miden de tres a cuatro milímetros de largo, mientras que el fruto de color café oscuro al madurar alcanza de quince a veinte milímetros de diametro.

Esta especie de desarrolla en las regiones tropicales contiguas a los litorales del Golfo y del Pacífico, en alturas no mayores de 500 metros sobre el nivel del mar, abarcando la planicie costera de Tamaulipas y regiones de los estados de Veracruz, Oaxaca, Chiapas, Yucatán, San Luis Potosí, Jalisco, Colima, Michoacán y Guerrero.

Las mayores concentraciones de esta especie comunmente conocida con el nombre de "Palma Real", se localizan en la costa de Oaxaca entre puerto escondido y Chacahua, así como en la región del Istmo de Tehuantepec. Con el material procedente de sus cogollos que alcanzan hasta 1.20 metros de largo y mediante diferentes técnicas se elaboran varios tipos de sombrero. Destacan los conocidos como "Campechanos" tejidos a mano por habitantes de la Mixteca Alta, para lo cual los tejedores

adquieren los cogollos transportados desde la costa del Estado de Oaxaca, pero principalmente de la región conocida como Istmo de Tehuantepec. En esta región, particularmente en los lugares aledaños a la costa del distrito de Juchitán (Unión Hidalgo, Chicapa de Castro y Chahuities) los campesinos cortan el cogollo cerrado, lo rajan y lo asolean durante tres días para que se decolore hasta quedar casi blanco. Posteriormente hacen manojos de cogollos para su venta, o bien tejen largas tiras que llaman cintillas, que miden ocho brazadas de largo por tres centímetros de ancho y están integrados por grupos de tres o de siete palmillas.

Esta cintilla se cose a máquina dándole la forma de una especie de cono el cual posteriormente se plancha en una horma especial que le da la forma del sombrero conocido como del Istmo. Con una mecánica similar se elaboran diferentes tipos de bolsas, esteras, abanicos, cestos, carpetas, portafolios, capazos, etc.

Género Carludovica

De esta especie destaca la denominada *Palmata* que se cultiva y explota principalmente en la localidad de Bacal en el Estado de Campeche, para manufacturar los sombreros finos conocidos como Jipijapa.

PROBLEMÁTICA ECONÓMICA Y SOCIAL

La región Mexteca sobre la que Fidepal enfoca sus principales acciones, abarca una superficie de 40 000 Km², comprendiendo la parte noroccidental de Estado de Oaxaca y áreas meno extensas de los estados de Puebla y Guerrero.

La población de la región Mixteca según el censo de 1980 era de 622 mil habitantes, de los cuales el 72.3% (450 mil) se ubican en el Estado de Oaxaca y el restante 27.7% (172 mil) habitan en distintas proporciones los estados de Puebla y Guerrero.

La región presenta un relieve sumamente abrupto, su clima es simicálido y subhmedo, tiene suelos calcáreos, lluvias irregulares y observa fenomenos de una ecología en deterioro. Las áreas ganaderas, parte de la superficie agrícola de temporal y las tierras improductivas, observan fuertes procesos de erosión; El 80% de la superficie física de la región está en agudo proceso de destrucción.

La economía de los habitantes de la región Mixteca se complementa de manera importante mediante los ingresos que les reditúa el tejido de la plama, actividad que por lo general desarrolla la totalidad de los integrantes del núcleo familiar.

La palma se explota en una superficie de 83,950 has; generando unos 300 mil jornales anuales mediante la elaboracion de sombreros y otras artesanías. La presencia de acaparadores

e intermediarios que compraban a precios sumamente bajos las artesanías de palma, menguando el ingreso de los tejedores, determinó la aparición de Fidepal, tanto para substraer a las comunidades indígenas de ese sometimiento económico, como para generar mayor volumen de empleo mejor remunerado y propiciar la industrialización de los productos de palma en su región de origen.

Intermediarismo y Explotación al Recolector y Tejedor de Palma

El constante incremento en los niveles de producción de artesanías de palma, principalmente de sombrero en grena, ha contribuido a considerar la región de la Mixteca, como la principal fuente de abastecimiento de estos productos a nivel nacional.

La producción de artículos de palma distingue dos procesos, por una parte la extracción de la palma en su estado natural y por otra el tejido de sombrero y de otros productos similares.

La extracción de la palma comprende actividades de recolección, secado y clasificación. La recolección se efectúa durante todo el año aunque se realiza en forma más intensiva en la época de secas, ya que la lluvia puede mancharla, demeritando su calidad y su precio. La actividad de secado se realiza al aire libre durante tres días y posteriormente se procede a su clasificación.

Es al término de este primer proceso donde se iniciaba la cadena de explotación, ya que el campesino productor realizaba la venta de su palma, en condiciones desfavorables, a un grupo de intermediarios que acaparaban la totalidad de su producción.

Los intermediarios revendían la palma en los mercados de consumo de la propia región Mixteca, llegando a cotizarse precios hasta tres veces superiores a como la habían adquirido originalmente, lo que les redituaba grandes ganancias.

En la región Mixteca el tejedor de palma pone a la venta sus productos aprovechando los días preestablecidos de mercado. En ellos el intermediario procura adquirirlos al precio más bajo posible. También efectúan la venta de sus productos de palma a pequeños comerciantes de sus comunidades, quienes llegaban a acaparar a nivel regional gran parte de la producción. Cabe mencionar que esta relación comercial se regula generalmente a través del trueque, y en el intercambio el campesino tejedor de palma resultaba perjudicado.

El surgimiento de Fidepal, S. de R.L. de I.P. y C. V., en 1973 modificó en cierta manera esta realidad, aunque en el lapso hasta 1983 su importancia como comprador fué mínima. Sin embargo, en 1984 se adoptaron las medidas necesarias, para reactivar la compra y producción de artesanías de palma, de tal forma que de 28 mil unidades de artesanías de palma que se venían adquiriendo mensualmente a los camposinos, se

aumento a 670 mil unidades mensuales, es decir, casi ocho millones de piezas de artesanía de palma durante 1984.

Ingreso y Empleo

Los habitantes de la región Mixteca desarrollan como principal actividad económica la relacionada con labores agrícolas, la cual se ha caracterizado tradicionalmente por su baja productividad debido, entre otros factores, a problemas en la tenencia de la tierra, erosión acelerada del suelo, escaso régimen pluviométrico, monocultivo, minifundismo, etc.

De la población total que se dedica a esta actividad se estima que el 60.0% obtiene ingresos aproximados de 15 mil pesos mensuales, cantidad que representa el 74% del salario mínimo promedio aprobado para la región.

El campesino mixteco ha encentrado en la recolección y tejido de la palma una manera de allegarse importantes ingresos adicionales a su merma económica familiar. Fidepal en 1984 apoyó a esos grupos marginados mediante la compra de palma y de sus artesanías generando 160,000 jornadas de empleos indirectos al mes.

Adicionalmente, Fidepal brinda empleo directo a 507 trabajadores en sus cinco Unidades industriales que se ubican en la Región Mixteca (Puebla, Guerrero y Oaxaca) y la Meseta Tarasca de Michoacán.

Del total de estos trabajadores, 341 (76.5%) se clasifican como obreros y perciben el salario mínimo autorizado para cada región, es decir, un promedio de \$820.00 pesos diarios. El resto de trabajadores 105 (23.5%) comprenden jefes de líneas de producción y recolección, mandos intermedios, personal administrativo y gerente general, quienes perciben ingresos superiores al salario mínimo teniendo como frontera los \$130,000.00 pesos mensuales.

La Palma Como Insumo

Las cinco Unidades de Producción Industrial que integran a Fidepal, utilizan como insumo básico lo que se ha dado en denominar artesanías de palma, esto es sombrero en grena, cinta, tela, trenza, etc., cuyas particularidades, diferencias y utilidad las define la calidad de la palma (cogollo) y la técnica que se adopte en su tejido.

La trenza de palma tejida en los estados de Guerrero y Michoacán se utiliza para la fabricación de diferentes modelos de sombreros denominados "Finos" de gran demanda en el mercado nacional y del exterior.

La cinta y la tela de palma son materia prima para la elaboración de bolsas para dama, y bolsas para el mercado, mientras que el sombrero en grena, mediante ciertos procesos de acabado, es de utilidad para la fabricación de sombreros y portamaceteros, producto que tiene como destino

principal el mercado de los Estados Unidos de Norteamérica.

Otros productos que elabora Fidepal teniendo como base la artesanía de palma son cestos roperos, manteles individuales, portapapelero, tortilleros, colchones playeros, portafolios, carpetas, capazos, porta vasos, sombrero para niño, sombrero para dama, tatamis, etc.

Las Unidades de Producción acorde con los fines para los que fueron creadas, no solo realizan labores propias de transformación e industrialización sino que colateralmente efectúan actividades de recolección, distribución y compra de artesanías de palma. Su acción contribuye a que los campesinos recolectores y tejedores obtengan mayores precios de garantía por sus productos.

ORGANIZACIÓN SOCIAL PARA SU APROVECHAMIENTO

Comités de la Palma

Los Comites de la Palma constituyen las organizaciones de los recolectores de palma y de los tejedores de artesanías en cada una de las localidades que atiende Fidepal en las Mixtecas de Oaxaca, Puebla y Guerrero.

El comité representa a los tejedores y recolectores de palma de una comunidad. Generalmente está integrado por un Presidente, un Secretario, un Tesorero y tres Vocales que son renovados cada año. En una comunidad de recolectores, el comité se encarga de pagar por la palma que entregan los campesinos recolectores a los precios de garantía vigentes. Para ello, Fidepal deja un fondo en el comité, recoge semanal o quincenalmente la materia prima. Si se trata de una comunidad de tejedores, entonces el comité no sólo se encarga de comprarle a sus socios las artesanías tejidas, sino también de proveerles de la palma necesaria y de administrar el dinero como fondo revolvente.

En la actualidad Fidepal opera con 208 comités de la palma, de los cuales 159 corresponden a localidades ubicadas en la Mixteca de Oaxaca.

Los comités de la palma son organizaciones representativas de la comunidad en la medida en que sus cuerpos directivos han sido elegidos democráticamente en asambleas de tejedores y recolectores de palma. Y justamente en esas poblaciones la recolección y tejido de la palma constituye la más importante actividad económica, cuando no la única.

La organización y funcionamiento de los comités de la palma constituyen una vertiente de concertación con el sector social, donde Fidepal aporta posibilidades de empleo e ingreso al llevarles trabajo organizado a los tejedores de la palma hasta sus comunidades.

CONTRIBUCIÓN DE FIDEPAL A LOS OBJETIVOS SECTORIALES DE LA ESTRATEGIA ECONOMICA Y SOCIAL DEL ESTADO

La acción de Fidepal se encuentra dentro de la política sectorial del Estado en materia de Bosques, Selvas y Zonas Áridas, así como de Desarrollo Rural Integral. Actualmente Fidepal está integrado por el Gobierno Federal, seis Sociedades de Solidaridad Social y 208 Comités de la Palma.

Sus principales objetivos son los siguientes:

- (1) Coadyuvar en la elaboración del nivel de vida de las poblaciones marginadas que viven del aprovechamiento de los bosques de palma.
- (2) Generar empleo e incrementar el ingreso de los campesinos recolectores y tejedores de palma, apoyando su trabajo organizado, proporcionándoles financiamiento e interviniendo directamente en la transformación industrial de las artesanías de palma y en su comercialización, a fin de retener para la región el excedente económico generado.
- (3) Eliminar a los intermediarios y acaparadores en este ramo, fijando precios de garantía que cada vez sean más remunerativos del trabajo artesanal.
- (4) Proporcionar asesoría técnica a las empresas de ejidatarios, comuneros y cooperativistas en el cultivo, preservación, aprovechamiento, industrialización y comercialización de la palma.
- (5) Promover en los Institutos Tecnológicos y Centros de Investigación, el estudio de procesos que optimicen el aprovechamiento del recurso, que aseguren la preservación y fomento de los bosques de palma y que capaciten a los campesinos en la operación y administración de su actividad.
- (6) Finalmente, coadyuvar al equilibrio de la balanza comercial mediante la exportación de artesanías de palma con alto porcentaje de mano de obra en su valor agregado.

Summary.--The inter-state organization known as FIDEPAL (trusteeship for the enhancement and development of palms and their products) was formed by a Presidential Decree in 1973. It was founded to enhance the social and economic conditions of the population of the "Mixtecas" region in the states of Oaxaca, Puebla and Guerrero, as well as the "Meseta Tarasca" in the state of Michoacán. Within the organization, the first palm committees were created--organizations of weavers and collectors of this natural fiber for the industrialization and commercialization of palm handicrafts, which currently integrate FIDEPAL and its production units.

245 La Calabacilla Loca (*Curcubita foetidissima*), un Recurso con Potencial en las Zonas Áridas¹

José Luz Chávez (Araujo)²

Resume.--La Calabacilla loco *Cucurbita foetidissima* (HBK), especie nativa de zonas áridas posee las siguientes características: semillas ricas en aceite y proteínas y alto contenido de almidón en su raíz. Características que sitúan a esta especie como un nuevo cultivo agrícola en estas regiones una vez domesticada.

INTRODUCCION

Es por todos conocido que las zonas áridas y semiáridas de México, así como de otras partes del mundo por sus características climatológicas y edáficas de estas regiones, no es posible utilizar grandes extensiones de tierra para la siembra de cultivos alimenticios; sin embargo, éstas poseen dentro de su flora un gran número de especies silvestres que pueden aprovecharse como fuente alimenticia o industrial, las cuales a la fecha no han sido objeto de investigaciones propias para su aprovechamiento.

Una de estas especies es la Calabacilla loca, especie silvestre y perenne que se encuentra creciendo naturalmente en estas regiones, cuyas semillas son ricas en aceite y proteínas, posee además un alto contenido de almidón en su raíz, así como un alto contenido de follaje el cual puede ser utilizado como forraje. Estas características hacen de esta planta una posible fuente de alimentos o de productos industrializables, por lo que se sitúa como un cultivo de futuro.

La Calabacilla loca ha sido estudiada por diversos investigadores quienes la consideran como un cultivo de amplio potencial agroindustrial, tales como los realizados por Curtis en 1946 quien reporta 33% de aceite y un 43% de proteína en sus semillas. De la información de Bemis et al. (1975, 1978), Berry et al. (1976) y la generada por UAAAN (1974-1984), se considera que la Calabacilla loca tiene el potencial necesario para valorarla como un cultivo alimenticio por sus características que posee.

¹ Ponencia presentada en la Reunión Sobre Manejo de Plantas en Zonas Áridas. Saltillo, Coahuila, México. Febrero 18-22, 1985.

² Ing. Agr. M.C. Encargado del Programa sobre Domesticación de la Calabacilla loca. Depto. de Fitomejoramiento, División de Agronomía de la UAA"AN", Buenavista, Saltillo, Coahuila. México.

La importancia de la Calabacilla loca estriba principalmente en el contenido de aceite y proteína de la semilla y almidón de la raíz. El contenido de aceite y proteína varía de 25.6 a 42.8 y 22.2 a 32.1%, respectivamente y de 50-60% de almidón en base a peso seco de las raíces (Curtis, 1972 y Barry, 1974). La importancia económica del aceite y proteína es vital en el presente, debido a que existe un fuerte déficit de alimentos nutritivos y aceites comestibles en nuestro país, lo cual hace necesario maximizar la eficiencia en aquellos cultivos en explotación y a la vez incorporar a la producción todos aquellos con potencial alimenticio e industrial.

CARACTERISTICAS GENERALES DE LA PLANTA

La Calabacilla loca *Cucurbita foetidissima* (HBK) se le conoce también con los nombres comunes de "Calabacilla", "Calabaza Bufalo", Chilicayote", "Calabacilla Amarga o Apestosa" y otros más (Stevenson 1948, Bemis y Whitaker, 1969).

La Calabacilla loca es una planta perenne, herbacea, tosca y aspera al tacto, crece durante los meses de abril a octubre (en México), posee numerosos tallos (guías) rastreros de 4-6 m de longitud cuando las condiciones son propicias; éstos son débiles, delgados y escabrosos; nacen de una raíz principal extendiéndose a todos los lados en forma circular; la mayoría de ellos producen ramificaciones secundarias las cuales también producen frutos.

La raíz principal es de considerable tamaño por lo que posee gran capacidad de almacenamiento de reservas. El peso de esta raíz es variable, habiéndose reportado pesos frescos de: 72 a 45 kg para raíces de 3 años de crecimiento, sin embargo lo más comunmente encontrado son raíces de 4-6 kg en dos años de crecimiento.

La reproducción de la Calabacilla loca en estado silvestre es principalmente asexual, ya que en cada nudo de las guías puede desarrollarse una raíz adventicia que da origen a una nueva planta,

formandose de esta manera densas colonias de plantas en lugares con captación de agua a través de escurrimientos naturales, o en regiones donde las lluvias son regulares.

Los frutos son por lo general redondos y periformes de diferente tamaño (4-8 cm), son de color verde con franjas blancas con pulpa muy filamentosa y amarga de color blanca. La producción de frutos por planta es muy variable; las semillas son pequeñas; oblongas-ovaladas de aproximadamente 12 mm de largo y 6-7 mm de ancho. El número de semillas por fruto varía de 200 a 300 semillas por fruto, con un promedio de 4 gr de peso por 100 semillas.

La Calabacilla loca posee una amplia distribución en Norte América desde el Oeste de los Estados Unidos hasta el Sur de Guanajuato; sin embargo, aunque su distribución dentro de la República Mexicana aún no ha sido completamente determinada, se puede encontrar en forma silvestre en prácticamente cualquier lugar del árido mexicano y regiones similares, o sea que se encuentra en casi todo el país.

Esta planta generalmente se desarrolla en un amplio y variado tipo de suelos, prosperando mejor en suelos profundos arenosos, pedregosos de poca pendiente, de regular humedad y bajo diferentes agroclimas. Comunmente se encuentra en terrenos removidos (áreas de disturbio) como a la orilla de: caminos, vías férreas, carreteras, basureros, corrales de ganado, canales de riego o todo aquel lugar donde se encuentre material orgánico con regular humedad, desde prácticamente el nivel del mar hasta alturas mayores de 2,000 msnm. Así mismo cabe hacer notar que la Calabacilla loca se desarrolla satisfactoriamente en suelos con problemas de sales.

POTENCIAL ALIMENTICIO Y/O INDUSTRIAL

El contenido de aceite y proteína de la semilla de Calabacilla loca compite con el de otras oleaginosas, entre ellas: soya, algodón, girasol y ajonjolí, ya que únicamente es superada por la soya (37.9%) y ajonjolí (41.3%) en cuanto a proteína y aceite se refiere (Fig. 1).

Por otro lado, el aceite de la Calabacilla loca contiene 61% de ácido linoléico, componente principal de los aceites comestibles y ácido graso esencial en la dieta alimenticia tanto en humanos como en animales. A este respecto la Calabacilla loca es superada únicamente por el cártamo (75%), (Fig. 2).

Asimismo, los residuos de la semilla (harina) una vez extraídos el aceite muestran ser una harina de buena calidad en base a su proteína. Los aminoácidos de esta planta han sido comparados con los del huevo, los cuales (estos últimos) son ligeramente superiores a los de la Calabacilla loca; sin embargo, presentan grandes posibilidades para utilizarse como una fuente de proteínas al incluirse en dietas alimenticias de animales

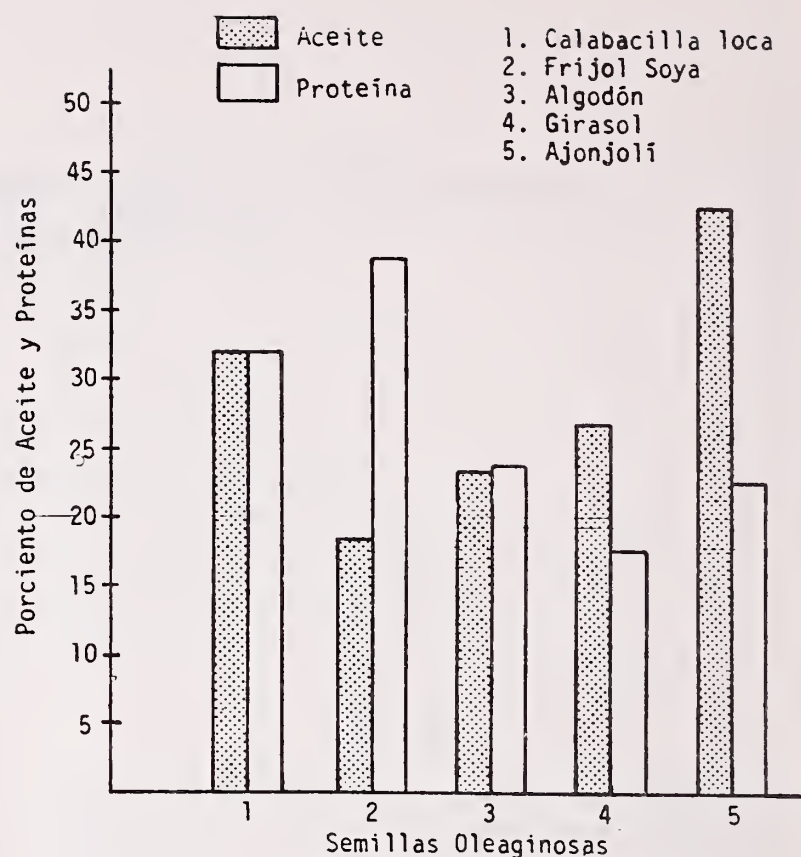


Fig. 1. Comparación de la semilla de Calabacilla loca con semilla de otras oleaginosas.

poligástricos (ruminantes: bovinos, ovinos, caprinos, etc.) y monogástricos (cerdos, aves, conejos, etc.).

El almidón de la raíz puede ser hidrolizado por métodos enzimáticos y químicos para obtener dextrinas, maltosa y glucosa.

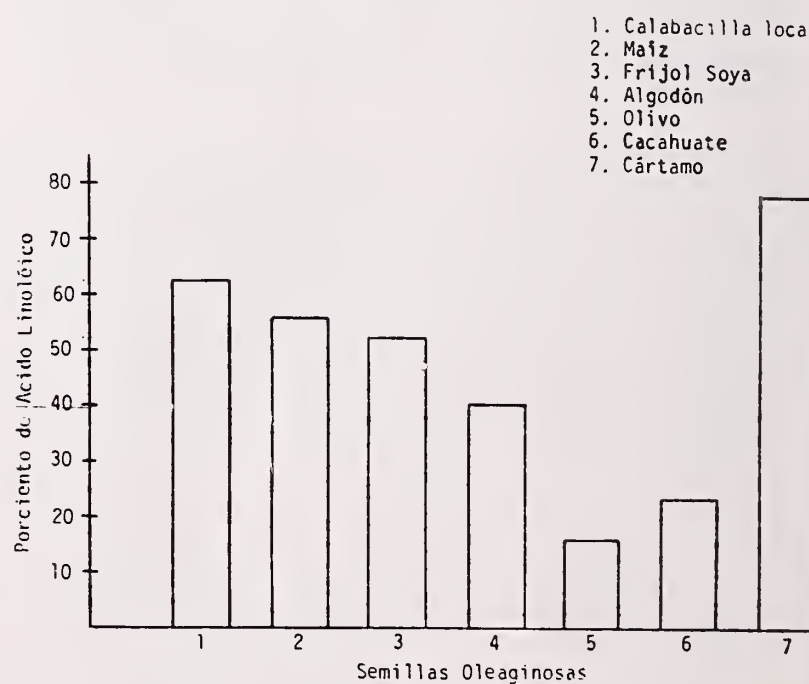


Fig. 2. Contenido de Acido Linoléico en Oleaginosas, comparado con el de la Calabacilla loca.

Cuadro 1. VOLUMEN DE SEMILLAS DE OLEAGINOSAS, GRASAS Y ACEITES VEGETALES IMPORTADOS POR MEXICO DURANTE 1972 Y 1978

P R O D U C T O	1 9 7 2		1 9 7 8	
	TONS	\$ (MILES)	TONS	\$ (MILES)
Semillas	26,682	125,600	957,697	5'909,138
Grasas y Aceites				
Vegetales	25,547	156,177	141,922	1'910,038

FUENTE: Secretaría de Programación y Presupuesto 1980.

IMPORTANCIA ECONOMICA COMO CULTIVO

En México la demanda de aceites y grasas vegetales va en aumento, año con año, debido a la alta tasa de crecimiento de la población y a la baja producción de los mismos.

Según de la Garza (1978) México tiene que producir 20,000 ton más de aceite año con año para cubrir las necesidades de consumo. De ahí que nuestro país se vea en la necesidad de importar grandes cantidades no sólo de semillas oleaginosas sino de aceite mismo. Así tenemos que en 1972 México importó 26,682 ton de semillas, en 1978 las importaciones fueron de 957,697 ton y para 1981 se compraron 1.3 millones de ton. Es obvio por lo tanto, que nuestro país tenga fuertes fugas de divisas tan solo por este concepto (Cuadro 1).

Por lo anterior, la Calabacilla loca se vislumbra pues, como una posible alternativa para solucionar en parte la escasez que se tiene de aceites y de otros productos industrializables una vez que esta especie se incorpore como un nuevo cultivo agrícola.

Asimismo, la Calabacilla loca a parte de considerarse como una fuente de alimentos, puede ocupar superficies que actualmente no son utilizadas en forma alguna por otros cultivos tradicionales tales como: maíz, frijol, trigo y otros, ya que esta especie requiere de mínima humedad y de suelos no muy especializados para expresar su máxima producción (frutos y/o semilla) bajo condiciones no muy benignas en las cuales otros cultivos no prosperan.

Por lo tanto, es importante hacer notar que en vista del déficit de semillas oleaginosas y en base al potencial que a este respecto presenta la Calabacilla loca, será sin duda una portación valiosa que coadyuvará a resolver en parte el problema de importación de aceites una vez que esta especie se incorpore como cultivo agro-industrial.

INVESTIGACIONES REALIZADAS

En base al potencial plenamente comprobado que posee la Calabacilla loca, la UAAAN conjuntamente con los organismos oficiales interesados en resolver en parte la situación que viven las zonas áridas y semiáridas de México inició en 1974 investigaciones tendientes a la domesticación de la Calabacilla loca para tratar de incorporarla como un nuevo cultivo oleaginoso.

Los estudios de domesticación se han llevado a cabo en los campos experimentales de: Matehuala, S.L.P., Cuencamé, Dgo., Navidad, N.L., Ocampo y Buenavista, Coah., localidades enclavadas dentro de las zonas áridas y semiáridas, pero de diferentes condiciones agroclimáticas.

Asimismo cabe hacer notar que para la domesticación de cualquier especie silvestre, se requiere de la participación de diferentes disciplinas para el conocimiento y manejo de la planta. En este renglón las investigaciones se han dirigido en básica y aplicada.

Por lo tanto, las investigaciones realizadas a la fecha en esta planta son las siguientes:

1. Colecta e introducción de materiales.
2. Pruebas de germinación de semillas (laboratorio, vivero e invernadero).
3. Pruebas de comportamiento de materiales nativos e introducidos.
4. Evaluación de materiales bajo riego y temporal.
5. Propagación vegetativa.
6. Evaluación de materiales sobresalientes.
7. Fecha óptima de cosecha.
8. Establecimiento de lotes semicomerciales para estimar: producción, costo e impacto socioeconómico.

Además de lo que a la fecha se ha generado, se esta investigando sobre cultivo de tejidos, reproducción asexual a través de partes vegetativas (guías) y la inducción de flores femeninas a

través de fitoreguladores para incrementar la producción de frutos por planta y/o unidad de superficie.

Por consiguiente en base a la información generada por las investigaciones realizadas, a las observaciones y experiencias obtenidas en esta planta se ha llegado entre otras, a las siguientes conclusiones:

1. La calabacilla loca por su condición xerófila, rusticidad y tolerancia a condiciones adversas, muestra ser un cultivo de futuro para las zonas áridas, semiáridas y regiones similares.
2. La Calabacilla loca a pesar de ser una planta que bajo condiciones naturales se desarrolla satisfactoriamente, ésta una vez establecida bajo cultivo se vuelve susceptible al ataque de plagas y enfermedades, así como exigente de humedad.
3. Para el establecimiento de siembras comerciales es necesario tomar en cuenta la época en la que regularmente se presentan las lluvias para asegurar el establecimiento de las plantaciones.
4. La Calabacilla loca puede establecerse en un amplio y variado tipo de suelos; sin embargo, prospera mejor en suelos removidos con buen drenaje (suelos de disturbio) y suelos ricos en materia orgánica.
5. La domesticación de la Calabacilla loca coadyuvará en la economía y vida de los habitantes de las zonas áridas, lo que favorecerá un cambio social para un mejor nivel económico y cultural de sus habitantes.

Lo antes expuesto no quiere decir que a la fecha ya se haya investigado todo lo necesario como para lanzar a la Calabacilla loca como un nuevo cultivo; sin embargo, considerando su potencial tanto alimenticio como industrial para el futuro, es de vital importancia generar el paquete agronómico que permita explotar a esta planta a nivel comercial, para lo cual se requiere ampliar e intensificar las investigaciones agronómicas, industriales y nutricionales que aún no se han realizado exhaustivamente. Por lo tanto se requiere del apoyo firme y decidido de las instituciones u organismos oficiales que buscan alternativas y/o soluciones ante la escasez de alimentos que cada día se agudiza.

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Summary.--The Buffalo gourd, Cucurbita foetidissima (HBK), a native species of arid lands, has seeds rich in oil and proteins, and a high starch content in its roots. Once it has been domesticated, this species may be cultivated as a new agricultural crop.

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**Arid Land Plant Research at the Caesar Kleberg Wildlife
Research Institute¹**

Edward Glumac, Peter Felker, Yashpal Goyal, Sharon Klass,
Charles Wiesman, Gary Cline, Isidro Reyes, Tom Tabone
and Sonia de Souza²

The Caesar Kleberg Wildlife Research Institute was established at the College of Agriculture of Texas A&I University in 1981 with a grant of \$3.3 million from the Caesar Kleberg Foundation for Wildlife Conservation to facilitate research aimed at enhancing the understanding of wildlife populations in the south Texas region. Better understanding of the wildlife habitat will lead to more productive management of local and exotic wildlife species.

Additional research is being conducted on several semi-arid and aridland plant species. These include mesquite (Prosopis spp.), Leucaena (Leucaena spp.), Cactus (Opuntia spp.), and saltbush (Atriplex spp.). A research priority of the Institute is the development of strategies to increase the economic returns to landowners from wildlife and their habitat. Within this context, the two primary goals of the aridland plant research group at Texas A&I are 1) to investigate the feasibility of establishing wood energy plantations in a semi-arid environment with Prosopis and Leucaena, and 2) production of animal fodder using Leucaena, Opuntia, and Atriplex species.

This paper will concern itself mainly with the production, management, and utilization of Prosopis and Leucaena species under non-irrigated and minimum fertilizer input conditions in annual rainfall zones of 450 and 760 mm.

RESEARCH TASKS

Tree legume research at Texas A&I University is divided into several areas. These are 1) tissue culture of clonal material 2) rooting of cuttings and 3) field trials of superior varieties.

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Tissue culture research is deemed necessary to produce true to type genetic material for species such as Prosopis which are self-incompatible (Simpson, 1977). As a result of self-incompatibility, trees propagated from the seed of Prosopis have a high variability. Tissue culture also has the capability to produce a million plantlets per year from a single auxillary bud.

Research has concentrated on Prosopis alba clone B₂V₅₀ which is a fast growing variety with few thorns. This clone was derived from a southern California P. alba ornamental accession (Felker et al, 1983) that had been one of the highest biomass producing accessions in a screening trial carried out at the University of California Riverside research plots. Although tissue culture of other Prosopis species has been carried out successfully (Goyal and Arya, 1984), P. alba has not yet been produced from bud explants. Leaves can be developed routinely from the explants. Leaves can be developed routinely from the explants, however, shoot development has been slow to develop for the B₂V₅₀ clone. Work is progressing in this area trying to determine optimal levels of cytokinins and auxins, evaluate basal salt media, and determine effects of environmental parameters.

An experiment carried out in 1983 examined 8 concentrations of cytokinins and 5 concentrations of auxins (indoleacetic acid). Although some shoot development did occur, it was not statistically significant between levels of the 2 factors. Three different IAA/kinetin ratios which produced shoots were selected for further study and the results showed that at the higher IAA concentrations leaf formation was reduced. Another experiment which examined two different cytokinins, benzylaminopurine (BAP) and kinetin showed no differences in leaf development between the two cytokinins.

There are currently 3 basal salt media which are widely used in plant tissue culture. Experiments have been conducted to test each of the 3 media at quarter, half, and full strength. These three media are Murashige-skoog, Gamborg B5, and "woody plant media." Results indicate that a greater response is obtained using full strength media and that the Murashige-skoog media appears to be the most promising. We believe that there may be a correlation between the amount of ammonium in the media and leaf

development as the Murashige-skoog media has $1650 \text{ mg L}^{-1} \text{ NH}_4\text{NO}_3$ as compared to 400 and 0 for the woody plant and Gamborg B5 media respectively. In addition, it now appears that larger explants have greater leaf development. This may indicate that a nutrient reservoir present in the explant, but not in the culture media is limiting explant development.

We decided to look at environmental factors such as light intensity and temperature because these have been shown to be important rooting of cuttings research. Earlier work had been done at ambient room temperature and at a light intensity of about 200 ft candles. Four different air temperatures of 25, 28, 31, and 34°C were investigated and light intensities of 450, 220, and 110 ft candles were used with one level of kinetin and IAA. The optimum combination from this experiment seems to be an air temperature of 28°C and 450 ft candle light intensity.

Tissue culture research has also centered on propagation of Leucaena leucocephala (K-67), one of the fastest growing varieties of this species. This plant has been relatively easy to propagate by tissue culture. Dr. Goyal has been able to routinely produce multiple shoots up to 7 cm long and has successfully dissected and subcultured portions of the multiple shoots (Goyal et al. 1985). With the proper nutrient/hormone combination about 95% of the node sections are induced to produce 2-3 shoots of about 4 cm average maximum length in 5 weeks. When the tissue culture medium is changed to a formulation high in auxins, roots are produced on 90% of the shoot sections. These rooted plantlets have been successfully transferred to a soil mixture and grown into seedling size plants.

As with tissue culture, rooting of cutting research is needed because of the obligate outcrossing nature of Prosopis. The first successful rooting of mesquite cuttings was reported in the Journal of Range Management (Felker and Clark, 1981). The technique used could produce 100% rooting of clone 0351 in the Spring but only 15% in November. Overall, about 70% rooting was obtained for 6 species having widely divergent origins (Felker and Clark, 1981).

A study was initiated in 1981 at Texas A&I to examine the influence of environmental parameters on the rooting of cuttings, specifically those of Prosopis alba clone B₂V₅₀. The environmental parameters looked at were photoperiod, light intensity, light quality, and temperature. These parameters were examined for the effect they had on percent rooting, maximum root length, and number of roots per cutting. We have found the optimum air temperature for rooting to be 35°C . Light intensities of greater than $520 \text{ uE m}^{-2} \text{ sec}^{-1}$ produced the greatest percent rooting, maximum root length, and number of roots per cutting.

The effect of length of photoperiods was examined to determine if there are differences that might affect the ability of cuttings to root. Four growth chambers were used to simulate photoperiods of 8, 12, 18, and 24 hours. The stockplants from which the cuttings were taken were also placed in the growth chambers. Cuttings from stockplants grown at each of the 4 photoperiods were examined at all 4 photoperiods for a total of 16 treatments. This allowed testing of stockplant by photoperiod interactions. Stockplants were moved to a new growth chamber every 3 weeks. This experiment was replicated 4 times. The statistical design of this experiment allowed for chamber and block effects to be examined, neither of which were significant ($P > 0.15$). The interactions between cutting and stock-plant photoperiod were also not significant. The best root development occurred at the 18-hr cutting photoperiods and the greatest average percentage rooting occurred at the 12-hr photoperiod, however these differences were not significant at $P = 0.05$.

As a result of knowing the optimal environmental parameters for rooting Prosopis alba B₂V₅₀, it was possible to achieve a rooting percentage of 83% during the period January-June of 1983 in a growth chamber. This work has been extended to a light bench in our greenhouse and rooting percentages of 75% has been achieved over a 6 month period.

FIELD TRIALS WITH PROSOPIS AND LEUCAENA

Field trials are being conducted on a 14 hectare site adjacent to the University, a 4 hectare site (Zachary Ranch) 160 km from Kingsville halfway between Hebbronville and Zapata, Texas and a 0.1 hectare site 10 km south of Kingsville. The Kingsville site have a annual rainfall of about 760 mm and the Zachary Ranch site about 450 mm. Prosopis is being evaluated under both rainfall regimes and Leucaena under the 760 mm regime. Management practices under investigation include screening trials, rotational cropping cycles, mineral nutrient requirements, and cultural-herbicide usage.

Prior to analyzing management techniques which will produce the highest yields, it is necessary to screen cultivars for selection of the highest yielding lines in a given geographic area. Initial work with Prosopis was carried out by Peter Felker at the University of California Riverside (Felker et al., 1982). A germplasm acquisition program was begun in 1978. About 150 Prosopis accessions were collected on a 3,000 mile field trip through the California desert. Another 300 came from a Peruvian collection maintained by Dr. Alva in Lima, Peru and Dr. Solbrig at Harvard University contributed 150. Other accessions were gathered from various sources in Hawaii, Argentina, Chile, Senegal, Sudan, South Africa, and the Caribbean. This

collection represents the largest germplasm pool of Prosopis in the world.

Within the last year, an IBM personal computer has been purchased to provide data management of this collection. All 1100 Prosopis accessions have been entered into a computerized filing system. This system allows for more efficient storage and retrieval of information as well as providing the capability to cross reference data entries according to individual characteristics.

A collection of over 75 Leucaena and 100 Cactus are also present as well as some Acacia and Pithecellobium accessions. This includes a rangewide collection of Leucaena pulverulenta made on a collection trip throughout south Texas in 1982.

A screening trial at Riverside, California in 1979 compared biomass production per tree for 51 accessions of Prosopis and 4 accessions 51 other tree legumes including Leucaena, Parkinsonia, Olneya, and Cercidium (Felker et al., 1983). Irrigation was used in this trial because of the low annual rainfall (65 mm/yr). Results of this trial showed a 160-190 fold range in means and a large range in variability within accessions. The Prosopis alba accessions were superior to all others in terms of dry biomass production. Clone B₂V₅₀ was taken from a tree belonging to accession 0194. It is this clone which is under intensive investigation in south Texas.

There are currently 9 experimental plantings of Prosopis which are determining pod, biomass, and timber production (Wiesman et al., 1984). As Prosopis has never before been planted as a plantation crop, we have had to devise our own methods for transplanting and maintaining these trees on marginal soils. The first step in this process involves preparation of land that is covered with brush. The existing vegetation must first be cleared off the land and burned. A moldboard plow is used to turn over the soil. Several passes are then made with a disk cultivator and Roundup herbicide is applied to eliminate remaining vegetation.

We have evaluated several herbicides for use in maintaining weed control in the Prosopis and Leucaena plantings and have eliminated some as being phytotoxic to the trees. One of these that is worth mentioning is the herbicide bromacil (Hyvar). This herbicide was applied to a Prosopis clonal plot which had been established in April of 1982 and to which bromacil had been applied in September of 1982 at the rate of 1.5 kg ha⁻¹ and 3.0 kg ha⁻¹ the following February. Phytotoxic symptoms were not observed until 5 months after the second application and by November of 1983 these plots had suffered irreversible damage.

We have also investigated the pre-emergence herbicides oxyfluorfen (Goal), oryzalin

(Surflan), alachlor (Lasso), metolachlor (Dual), and napropamide (Devrinol) at two different rates for use in transplanting L. leucocephala (K-67) and P. alba (Felker et al., 1984). Percent weed cover was evaluated at 45, 75, and 105 days after planting and basal diameters of all trees were measured 110 days after transplanting. Existing regression equations were used to convert basal diameters to dry weights. The greatest dry biomass per tree was achieved with Oryzalin at a rate of 2.8 kg a.i. ha⁻¹ (2X). Oryzalin also provided the best combination of grass and forb control. We feel that some kind of weed control is necessary when trying to establish leguminous trees in semi-arid conditions because of the competition with grasses and forbs for available moisture. This control could be maintained with herbicides in combination with mechanical cultivation at costs which would be reasonable especially if carried out on larger scale plantations. Costs for oryzalin at the 2X rate on a per hectare basis in 1981 dollars were \$77 (Felker et al., 1984). This cost could be reduced using oryzalin at the 1X rate in combination with mechanical cultivation. A leaf second herbicide trial was established in 1984 to compare weed control and phytotoxic effects of inexpensive long residual herbicides for use on trees that have already been established. Herbicides that are being tested include Dachthal, HyVar, Krovar, Karmex, Solicam, and Simazine at two rates of application. The 4 ha plot at Zachary Ranch was established because it is in a region that has only 450 mm rainfall, about 300 mm less than Kingsville. The mean daily July maximum temperature is 38°C whereas Kingsville is 36°C. Survival rates of the 3 clones and 1 seed propagated accession established in 1983 ranged from 86.7-99.7% and the dry biomass per hectare ranged from 1,440 kg ha⁻¹ to 3,560 kg ha⁻¹ 9 months after planting. These trees were planted on a 3m x 3m spacing. An electric fence has been constructed around these plots to protect the coppice regrowth from the abundant deer population in the area.

We have compared two different types of containers for use in transplanting seedlings to the field. One container is a 3.8 cm x 3.8 cm x 38 cm cardboard container that is open at the bottom and is left on the seedling when transplanted to the field. The other container is a 20 cm plastic dibble tube which is removed just prior to planting in the field. Survival percentage and dry biomass are different for Prosopis and Leucaena. The cardboard plant bands which are left on the seedling gave higher rates of survival for both Prosopis and Leucaena, however the dry biomass per tree was higher in the Leucaena using the plastic dibble tubes and no significant difference was observed for Prosopis. This difference may be due to a difference in root systems. Prosopis has a root which goes down straight for water as opposed to the roots of Leucaena seedlings which are more fibrous and may be constricted in the cardboard containers.

Leucaena is being tested at our Kingsville plots for production as a woodfuel source and for animal fodder. Leucaena has been distributed worldwide for use as woodfuel, animal forage, reforestation, soil improvement, and as a source of protein (NAS, 1984). It grows best in areas receiving from 1000-3000 mm of rainfall per year, although it is tolerant of droughts and can survive in some areas receiving as little as 250 mm rain (NAS, 1984). The soil on which Leucaena grows seems to be important for high rates of productivity. It has been stated that Leucaena has the capability to grow and break up impervious soils (Dijkman, 1950), however our experience is that certain soil types can greatly reduce productivity. We have 2 soil types on which Leucaena is growing. The Orelia series soil is underlain at 15 cm by a natural hardpan which appears to be restricting root penetration or water movement whereas an adjacent Willacy series soil lacking the hardpan is moderately permeable to a 60 cm depth. Yields of L. leucocephala (K-8) on the Willacy soil (8,000 kg ha⁻¹) have been 4 times those on adjacent Orelia hardpan soil (2,000 kg ha⁻¹). We are attempting to correlate plant tissue analysis and physical properties with biomass yields for the particular experiment.

A screening trial was established in March of 1983 to compare 65 accessions of Leucaena, 37 L. pulverulenta, 25 L. leucocephala, and 1 L. retusa. A randomized complete block design was used consisting of 5 trees of each accession in 4 blocks for a total of 20 trees per accession. Survival percentages and growth rates are being monitored to select for the highest biomass yielding accessions. The highest yielding trees are L. leucocephala accessions, especially the K varieties developed at the University of Hawaii by Dr. Brewbaker (K-8 and K-67). We also have several other non-selected leucocephala varieties that show potential for the south Texas region.

The unselected L. pulverulenta accessions, although not as fast growing as the K-varieties appear to have some advantage in ability to tolerate mild freezing temperatures. A freeze in the first week of December 1984 saw the temperature fall to -4.5°C and 10 hr of below freezing temperatures were recorded. Most of the leucocephala varieties were injured as evident by the almost total loss of leaves, whereas the pulverulenta accessions showed only very slight signs of injury.

A record breaking freeze in December 1983 which sent temperatures plummeting to -12°C killed all accessions with the exception of L. retusa which was completely undamaged. This freeze had a probability of occurring about once in 125 years (LeHouerou, 1984). The potential exists for transferring the cold tolerance of L. retusa to the more prolific varieties of L. leucocephala or L. pulverulenta (Brewbaker, 1984) by making selected crosses of these species.

A promising use for Leucaena in semi-arid conditions is for forage production, either in a livestock grazing system or for mechanical harvesting and processing systems. We have purchased a John Deere Model 25 ensilage cutter and our initial experience is that large quantities can be easily cut using this equipment. We are investigating ways to process the cut material, by drying, ensiling, or pelletizing.

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RESUMEN

A partir de 1981, el Caesar Kleberg Wildlife Research Institute de la Universidad de Texas A&I ha efectuado investigaciones sobre especies de tierras aridas y semiaridas tales como Prosopis, Leucaena, Opuntia y Atriplex. Los objetivos a largo plazo son los de obtener beneficios economicos para los rancheros de la region del sur de Texas.

Se han usado tecnicas de cultivo de tejidos para propagar y multiplicar Prosopis debido a la alta variabilidad en la progenie propagada a traves de semillas. Experimentos en condiciones de laboratorio han sido efectuados para determinar los niveles optimos de auxinas, citoquininas y nutrientes para facilitar el desarrollo de los brotes y de las raices en el material vegetal de clon. Leucaena leucocephala (K-67) ha sido exitosamente propagada de esta manera.

La investigacion sobre el enraizamiento de los fragementos clonales se ha centrado sobre Prosopis clon B₂V₅₀. Varios parametros

ambientales que afectan la capacidad de enraizamiento de los fragmentos, tales como temperatura, fotoperiodo y la intensidad de la luz, estan siendo investigados para maximizar el enraizamiento.

Variedades superiores de Prosopis y Leucaena han sido probadas en condiciones naturales bajo dos regimenes pluviales. Prosopis ha sido evaluado en regimenes pluviales de 760 y 450 mm anuales y Leucaena en una area con 760 mm de lluvia anual. Herbicidas pre-emergentes y de post-establecimiento se han evaluado para controlar la competencia con malezas por humedad, un factor critico en condiciones de aridez o semi-aridez.

Se han investigado el potencial en tres especies de Leucaena para producir una biomasa de madera o farraje en una area que es sujeto de frecuentes heladas. El tipo de suelo en el cual Leucaena crece es aparentemente un factor limitante para una alta productividad.

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Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

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Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526